DENTAL FLUOROSIS IN A RURAL NIGERIAN COMMUNITY: IS THE WATER TO BLAME?

By

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Submitted in partial fulfillment of the requirements for the degree of Bachelor of Science

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IS THE WATER TO BLAME?

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DENTAL FLUOROSIS IN
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DEDICATION

I dedicate this research to my dear mother, late Asp. Monica Moses, my father late Hon. Engr. Anthony Lazarus Madwatte, and the whole community of Zing Local Government Area of Taraba State.
ACKNOWLEDGEMENTS

I will like to appreciate God Almighty for the grace and strength to execute this project. I will also like to acknowledge the efforts of my supervisors Dr. Jennifer Tyndall and Linus Okoro for their relentless efforts in guiding me.

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ABSTRACT

Drinking water can contain fluoride which is effective in preventing dental caries at concentration of ≤1.5 mg/L however at concentrations ≥1.5 mg/L, it could lead to dental fluorosis. Dental fluorosis is a disorder that occurs due to excessive fluoride intake during the mineralization of the teeth, resulting in an uneven distribution of brown and yellow coloration. I assessed fluoride levels in 19 samples of natural water sources (such as boreholes, streams, and wells) and commercial drinking water sources (such as sachet and bottled water products) in Zing Local Government Area, Taraba State, northeastern Nigeria, I then determined the prevalence of dental fluorosis in 135 children, aged 10 to 17 years, who were born in Zing. Using cross tabulations and logistic regression modelling, I evaluated factors that might influence whether a child had dental fluorosis, such as dental care habits and drinking water source. Fluorosis occurred in 111 respondents. Fluoride levels exceeded the World Health Organization permissible limit of 1.0mg/L for tropical environments in most borehole samples, while most stream and well samples did not exceed this limit. The regression model showed that odds of a child having dental fluorosis were higher for
those children who drank borehole water compared to those who do not (OR = 8.522), while the odds of having fluorosis decreases for children who drink from stream water (OR = 0.203). Consequently, community boreholes may need to be de-fluoridated and there should be community awareness about the sources of water with high fluoride concentrations.

Keywords: Boreholes, dental fluorosis, drinking water, fluoride, Nigeria, streams, wells
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LIST OF ABBREVIATIONS

WHO – World Health Organization

UNICEF – United Nations Children Fund

ppm – Parts per million

mg/L – Milligram per liter

mg/kg – Milligram per kilogram

km - Kilometer

F⁺ - Fluorine ion
CHAPTER 1

INTRODUCTION

Water is a very important basic requirement for human life and that is why water quality is an important factor and a key area of concentration in public health. Fluoride, is an important element considered to be beneficial at low concentrations and toxic at high concentrations when present in water. Fluoride is toxic as a result of its strong affinity for calcium, this gives it the ability to react with structures that are made of calcium such as teeth and bones. The World Health Organization (WHO) guideline for permissible fluoride concentration in drinking water is set at 1.5 mg/L (WHO, 2011). However, the WHO has emphasized the need for national authorities to set national fluoride standards taking into consideration climatic condition, fluoride intake from alternative sources, and daily water intake (Lennon, Whelton, O'Mullane, & Ekstrand, 2005).

Common techniques used to detect fluoride levels include fluoride ion selective electrode method, calorimetric methods, ion chromatography methods, and use of photometer (Agency for Toxic Substances and Disease Registry, 2001).

For many years, there has been a global public health debate about both the beneficial and adverse effects of fluoride in water sources (UNICEF, 1999). This debate first came about in the 1930s and 1940s when a study revealed that fluoride concentrations below 1.5 mg/L in water is effective in preventing tooth decay, otherwise known as dental caries (Dean & Brandt Jr, 1974). According to Jones et al. (2005), dental caries affects approximately 60-90% of school children in most
developed countries. In addition, Jones et al. (2005) also identified Latin American and Asia as the continents with the highest prevalence of dental caries.

According to Gussy et al. (2008), fluoride provides protection to the teeth in two ways; pre and post eruption. The pre-tooth eruption occurs while the tooth is still developing. Dental tissues, especially the enamel, are incorporated with fluoride giving them the ability to resist de-mineralization. The post-eruptive stage occurs when there is topical contact between the fluoride and erupted teeth enhances the ability of the teeth to replace surface minerals on the teeth. In addition, Jones et al. (2005) highlighted that fluoride improves the chemical structure of the dental enamel and it also reduces the acid formation ability of plaque bacteria. All these properties further emphasized by gussy et al. (2008), makes fluoride an effective agent in preventing dental caries.

Despite the effectiveness of fluoride in combating dental caries, in high concentrations, fluoride could lead to a condition called dental fluorosis (Dean, 1934). Dental fluorosis, also referred to as Colorado brown stain, is a disorder that occurs during the mineralization of the teeth, resulting in an uneven distribution of brown and yellow coloration. McKay (1952) refers to dental fluorosis as the mottling of the enamel. The teeth appear opaque, disfigured, and discolored (Soto-Rojas et al., 2004). This defect occurs in children between the ages of 0 and 8 when the teeth is still developing (Beltran-Aguilar, Barker, & Dye, 2010).

Dean and Brandt Jr. (1974) were one of the first researchers to show the relationship between dental caries and dental fluorosis in respect to fluoride concentration in
community water. Their study showed that 4-5% of the 114 children in their study who drank from community water that had fluoride concentration of 0.6 – 1.5 ppm were dental caries free while 22-27% of the children who drank from community water of concentrations above 1.5 ppm were caries free and showed dental fluorosis. More studies have also shown the inverse relationship between dental fluorosis and dental caries. Marya et al. (2004) showed that in Haryana, India, as the level of fluoride rose from 0.5 – 1.13 ppm, the prevalence of dental caries reduced from 48.02% to 28.07% without very significant increase in prevalence of dental fluorosis. However, as fluoride concentrations continued to increase to 1.51 ppm, the prevalence of dental fluorosis increased as well (Marya et al., 2004).

In the last two decades, there has been a considerable reduction in the incidence of dental caries on the other hand, there has been reasonable increases in the number of cases of dental fluorosis (Buzalaf, Cury, & Whitford, 2001). These changes in the patterns of dental health are mainly due to the increased fluoridation of community water evident in countries like the United States, Australia (Fagin, 2008; Gussy et al., 2008). Research conducted in Australia showed that since the introduction of community water fluoridation, 90% of children (12 years of age) had experienced dental fluorosis. This number however, in 1994 had reduced to 42.5% and in 1999, it reduced to 35.5% (Gussy et al., 2008).

During the process of tooth formation, amelogenins: proteins that the build-up of hydroxyapatite crystals, are broken down and eliminated from the matured enamel after tooth development. When fluoride is ingested at higher concentrations than the normal, it interferes with tooth development causing amelogenins to remain in the
developing tooth longer than normal causing the crystalline structure of the enamel to be tampered with. When the enamel finally develops and erupts, the teeth is seen to have unevenly distribution of lines and color. At more severe situations, the teeth are pitted with brown or yellow coloration (Fagin, 2008). This is why dental fluorosis usually occurs in children (0-8 years) whose teeth are in the process of still developing. This results in an increased risk of having an aesthetic change or fluorosis in the permanent teeth when children are exposed to high levels of fluoride during this period (Alvarez, et al., 2009).

Dental fluorosis is a public health concern in places where the concentration of fluoride in water exceeds the prescribed levels (Soto-Rojas et al., 2004). Brown (2012) reports that 38% of children (15 years of age) in fluoridated Irish communities have shown signs of having dental fluorosis. Despite that dental fluorosis is mainly caused by naturally occurring fluoride in natural drinking water sources, it is also associated with wide use of fluoridated products, such as toothpaste, supplements, and nutrition (Akpata, Danfillo, Otoh, & Mafeni, 2009).

Many fluoridation programs have been implemented in several countries worldwide so as promote a decrease in dental caries. In some Latin American Countries, fluoridation of salt and water have been largely introduced (Jones et al., 2005). The total amount of fluoride obtained from other sources of consumption during tooth development contributes to the risk of having dental fluorosis (Buzalaf et al., 2001). The severity of dental fluorosis depends on the length of exposure to fluoride, response of the individual, nutritional factors, and physical activities. Some
researchers have also shown that living at high altitudes and climatic conditions also play a role in the prevalence of dental fluorosis (Soto-Rojas et al., 2004).

Climatic conditions also play a role in the prevalence of dental fluorosis in some regions. Although the WHO global recommendation for fluoride concentrations in water is ≤ 1.5 mg/L, the organization advises that permissible level is ≤ 1 mg/L in tropical regions (UNICEF, 1999). This is simply because in warmer climates, people perspire more and tend to drink more water, hence consuming more fluoride compared to people who live in temperate regions. In Africa, dental fluorosis has been associated with fluoride levels in natural drinking water sources as low as 0.1–0.4 mg/L (Akpata, 2014). In addition, research has shown that in southern parts of Ukraine where the climate is warmer than other parts of the country, fluorosis is evident at concentrations lower than 1.2 mg/L (Fordyce et al., 2007). Marya et al. (2014) suggested that in warm parts of the United States, fluoride content in water sources should range between 0.7 – 1.2 ppm.

Dental fluorosis is not a disease, but rather a defect hence various societies and cultures perceive it differently. It is considered to be an aesthetic problem because it changes the natural coloration of the teeth hence making individual with fluorosed teeth feel embarrassed by this condition. The smile greatly affects people’s view on attractiveness, it plays a role in a person’s confidence and self-esteem (Hassebrauck, 1998, as cited in Molina-Frechero, et al., 2017). In Brazil, there have been cases of people reported to be stigmatized and discriminated as result of the color of their teeth. These people were deprived of smiling and having a normal social life (Santa-Rosa et al., 2014). Brown (2012) conducted a study in order to determine the rate at
which individuals with fluorosed teeth perceive it as an aesthetic problem. The study revealed that cases categorized as “mild” or more were identified by the affected individuals as an aesthetic problem. Study conducted by Molina-Frechero et al (2017) in Durango city of Colorado showed that 68% of adolescent with dental fluorosis showed concern about the colour of their teeth. A study conducted in Palestine revealed that 87.5% of the 350 children with fluorosis studied do not accept the appearance of their teeth as a result of the colour, in addition, 99.7% of the children believe that the appearance of the teeth affects personality and aesthetic appearance (Abuhaloob & Abed, 2014).

Asides from dental fluorosis, high intake of fluoride leading into accumulation in bones can also result into skeletal fluorosis. This condition is characterized by joint pains and stiffness. Furthermore, much higher concentrations can cause atherosclerosis and other bone deformities. These conditions are very evident in communities such as the Rift Valley and in China where very high concentration of fluoride exists naturally in groundwater (WHO, 2010). Dan (2008) highlighted that the ability of fluoride to tamper with the crystalline structure of bone could lead to increased risks of fractures. Though there are few studies on this, fluoride intake has also been associated with hypersensitivity (Kaminsky, Mahoney, Leach, Melius, & Miller, 1990). Few studies have raised fears that fluoride could lead to proliferation of osteoblast cells (bone-building cells) and result into the formation of malignant tumors (Fagin, 2008). Sutton et al. (2012) suspects that exposure to high naturally occurring fluoride in water contributes to cardiovascular dysfunction. Animals who ingest these fluoride toxic substances also prone to fluorosis; fluoride toxicity is not
just harmful to human health but also affect animal husbandry, agricultural crops and plants in their natural habitat (Abugri & Pelig-Ba, 2011).

Research conducted by Indermitte et al. (2009) compared Estonia’s population exposure to different natural water sources with different fluoride concentrations and risk of dental fluorosis and the findings showed the increased risk of fluorosis in populations where the people were exposed to water with fluoride concentration higher than the WHO accepted value of 1.5 mg/L (Table 1).

Table 1. The prevalence of dental fluorosis in Estonia in respect to different concentrations of fluoride in natural drinking water sources. (Source: Indermitte, Saava, & Karro, 2009).

<table>
<thead>
<tr>
<th>Fluoride content (mg/L)</th>
<th>No of children</th>
<th>Children with fluorosis (cases)</th>
<th>Healthy subjects (controls)</th>
<th>Prevalence of fluorosis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.0</td>
<td>1,024</td>
<td>69</td>
<td>955</td>
<td>6.7</td>
</tr>
<tr>
<td>1.0 – 1.5</td>
<td>984</td>
<td>120</td>
<td>864</td>
<td>12.2</td>
</tr>
<tr>
<td>1.51 – 2.0</td>
<td>386</td>
<td>147</td>
<td>239</td>
<td>38.1</td>
</tr>
<tr>
<td>2.1 – 3.0</td>
<td>167</td>
<td>75</td>
<td>92</td>
<td>44.9</td>
</tr>
<tr>
<td>3.1 – 4.0</td>
<td>30</td>
<td>16</td>
<td>14</td>
<td>53.3</td>
</tr>
<tr>
<td>&gt;4.0</td>
<td>36</td>
<td>32</td>
<td>4</td>
<td>88.9</td>
</tr>
<tr>
<td>Total</td>
<td>2,627</td>
<td>459</td>
<td>2,168</td>
<td>17.5</td>
</tr>
</tbody>
</table>

According to UNICEF (1999), dental fluorosis is endemic in more than 25 countries globally (Fig. 1), some of these countries affected globally include China, Japan, India, Kenya, Uganda and Mexico amongst others. In addition, UNICEF (1999) adds that dental fluorosis is endemic in 15 out of 32 states in India. Studies on dental fluorosis in relation to different concentrations of fluoride in drinking water have been conducted in various countries (Table 2).
Fig. 1. Countries with endemic dental fluorosis due to excess fluoride in drinking water (Source: UNICEF, 1999).

Table 2. Fluoride concentration is several water sources studied across different countries (Source: Lorna, Start, Dave, & Jamie, 2006).

<table>
<thead>
<tr>
<th>Study location</th>
<th>Age group studied</th>
<th>Range of fluoride concentration (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi Arabia</td>
<td>12–15</td>
<td>0.5–2.8</td>
</tr>
<tr>
<td>Norway</td>
<td>5–18</td>
<td>0.1–8.0</td>
</tr>
<tr>
<td>India</td>
<td>&lt;18</td>
<td>1.1–9.8</td>
</tr>
<tr>
<td>India</td>
<td>&lt;16</td>
<td>0–10.8</td>
</tr>
<tr>
<td>USA</td>
<td>8–16</td>
<td>&lt;0.3–4.07</td>
</tr>
<tr>
<td>Tanzania</td>
<td>9–13</td>
<td>18.6†</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>7–20</td>
<td>1.5–36.0*</td>
</tr>
<tr>
<td>India</td>
<td>5–15</td>
<td>3.7–6.2</td>
</tr>
<tr>
<td>China</td>
<td>not specified</td>
<td>&lt;0.3–5.0</td>
</tr>
<tr>
<td>Kenya</td>
<td>11–15</td>
<td>0.1–0.93</td>
</tr>
<tr>
<td>USA</td>
<td>8–10 &amp; 13–16</td>
<td>&lt;0.3–1.0</td>
</tr>
</tbody>
</table>
Research conducted in Ghana and Tanzania showed that a good number of sources of water exceeded fluoride concentration of 20 ppm in central parts of Tanzania and 4 ppm in parts of Ghana. The water samples analyzed (23% and 57% in Ghana and Tanzania respectively) were all in excess of WHO permissible levels. Dental fluorosis is prevalent in these areas (Smedley et al., 2002).

In Nigeria, only a few studies have been conducted to determine the relationship between fluoride exposure and dental fluorosis. Akpata et al. (2009) conducted research so as to map out fluoride concentration in water sources that cut across Nigeria. From their findings, 62% of the 109 local governments had fluoride concentration of 0.3 ppm or less. Some water samples showed high fluoride content that exceeded 1.5 ppm and a certain well in their studies had maximum fluoride concentration of 6.7 ppm (Akpata et al., 2009).

![Fig. 2. Sources of drinking water in Nigeria (Source: Akpata et al., 2009).](image-url)
Dental fluorosis has been identified in many Nigerian cities, some of which include Abeokuta, Katsina, Maiduguri, and Yola (El Nadeef & Honkala, 1998). Water samples collected over different zones of Nigeria showed variations in fluoride content of water. In western Nigeria, water samples had between 0.0-0.4 ppm fluoride content. While in northern Nigeria, water samples tested between 0.0-1.2 ppm fluoride content (El Nadeef & Honkala, 1998). One of those researches conducted by El Nadeef and Honkala (1998) showed that in central Nigeria particularly Bauchi and Plateau states showed that fluoride concentrations detected were between 0.0-0.4 ppm and 51% of the subjects had dental fluorosis. Nigeria has a humid tropical climate where temperature ranges between 28-32°C, this suggests in the results that temperature played a role (Akpata et al., 2009). Tropical regions where there is more daily water consumption often show dental fluorosis even at low concentrations of fluoride in drinking water. Despite that the WHO have set a
guideline of 1.5 ppm fluoride concentration in water, Brouwer et al. (2009) recommended a limit of 0.6 ppm fluoride concentration in drinking water in Senegal. In addition, Akpata et al. (2009) recommended a range of 0.3 – 0.6 ppm fluoride concentration in drinking water for a warm country like Nigeria. Drinking water in Nigeria is supervised by the Ministry of Health and it is responsible for ensuring that water consumed via different sources are up to required quality (Standard Organization of Nigeria, 2007)

**Signs of Dental Fluorosis**

The clinical symptoms as described by Cutress and Suckling (1990) are the presence of thin white lines observed across the surface of the teeth. These white lines are opaque and appear to align with the perikymata pattern. There may be complete opaqaing of the incisel and cusps edges and the marginal ridges. In moderate fluorosis cases, the lines appear to be cloudy and unevenly scattered on the teeth surface. As the severity of the case increases, the whole teeth surface becomes opaque with some areas exhibiting brown/yellowish coloration (Cutress & Suckling, 1990).

**Sources of Fluoride in the Environment and Human Body**

There are several media through which fluoride gets circulated through the environment and human body. The diagram below was adopted by the World Health Organization to summarize several sources and means through which fluoride circulates the bio-geosphere. According to Bhat et al. (2015), there are two major channels that fluoride pollutes the environment: normal and anthropogenic. The major source of fluoride in the surface of the earth is rock minerals. This is the normal or in other words natural channel through which fluoride is exposed into the
environment. Another form of normal or natural channel is through volcano eruptions. Madison and Firehole rivers found at Yellowstone Park in the United States are geothermal areas where fluoride concentration ranges between 1 to 14 ppm. These regions with thermal waters such as New Zealand, Pyramid and walker lakes contain approximately 13 ppm fluoride concentration (Camargo, 2003).

![Fluoride circulation diagram](image)

**Fig. 4.** Fluoride circle. Fluoride circulation in the biosphere through various sources (Source: WHO, 2002).

**Anthropogenic Factors**

The anthropogenic channel is through human activities due to industrialization. The introduction of pesticides that contain fluoride have contributed to the presence of fluoride in soils and water surrounding water bodies. Burning of fossil fuels and motorization are also anthropogenic factors that have contributed to the presence of fluoride in the environment (Bhat et al., 2015). Studies in the Ukraine showed enhanced environmental concentrations of fluoride as a result of coal mining (Fordyce et al., 2007). Industries producing steel, zinc, fertilizers, glass and ceramic are sources of fluoride release into the environment (Bhat et al., 2015).
The development and the use of chemicals such as hydrogen fluoride (HF), fluorosilicic corrosive (H SiF), sulfur hexafluoride (SF), sodium fluoride (NaF), and phosphate composites (release fluoride into agricultural soils) have also become channels through which fluoride is released into the environment/human body (Bhat et al., 2015). The WHO (2010) revealed in their report that other channels through which fluoride gets into the environment is evident in large commercial laundries and semi-conductor industries who use hydrogen fluoride - which is very soluble in water and in fumigants made with sulfuryl fluoride.

In addition, WHO has added that in Canada and Netherlands, approximately 23,500 and 46,600 tons of fluoride are released to the environment via industrial sources (WHO, 2002). The Kitimat River and Sagueny River in Canada all contain approximately 10 times more fluoride concentration because aluminum smelters are situated close to these rivers (Camargo, 2003). According to Peterson et al. (2008), the coal burning in South-western China is the main cause of endemic dental fluorosis in the region. The coal burning in China has led to fluoride pollution in 14 Chinese provinces eventually leading to skeletal fluorosis and dental fluorosis suffered by 2.9 and 39 million people respectively in that those provinces (Peterson, Kwan, Zhu, Zhang, & Bian, 2008).

Studies by HanDong et al. (2011) in Guizhou China, showed that the cause of endemic fluorosis which include both dental and skeletal fluorosis alongside other deformities is as a result of coal burning. Fluorosis in this region is called coal-burning fluorosis (HanDong, Yanci, Joseph, Yatzor, & Ping, 2011).
**Natural Fluoride in Water**

Waters that are found naturally at rocky geographic locations are known to contain high fluoride content as a result of the mineral leaching from these rocks and mountains. Natural fluoride in water have often been associated to areas with high altitude due to presence of rocks and mountains. Studies conducted in Mexico, Kenya and Tanzania have shown that high prevalence of dental fluorosis is associated with high altitude (Soto-Rojas et al., 2004).

The Rift Valley in East Africa is known to have waters that contain high fluoride content naturally. Other geographical locations that are known to contain naturally very high fluoride content in their water include parts of Egypt, Algeria, Japan, Thailand and China among many others (O’Mullane et al., 2016). Due to the abundance of fluoride in the earth’s crust, waters are known to naturally contain fluoride in them just in different concentrations. Lakes and rivers are known to contain fluoride concentrations as low as 0.5 ppm and as high as 95 ppm (Recorded in Tanzania). A case study done in the Rift Valley revealed that Lake Nakuru contained the highest naturally existing fluoride concentration found to be 2800 ppm (O’Mullane et al., 2016).

High fluoride concentration occurring naturally in groundwater has become an area of concern. Countries such as Mexico, China, Argentina and India among many others are known to have high-fluoride containing groundwater. India, China and Mexico amongst these countries are estimated to have about 70, 45 and 5 million people suffering from severe endemic fluorosis respectively (Smedley et al., 2002). In addition, studies conducted in 19 Mexican states showed that 7 of those states
have naturally occurring high fluoride content in their drinking water (Soto-Rojas et al., 2004). Generally, fresh water that are not polluted contain fluoride content that range between 0.01 to 0.3 ppm meanwhile polluted salt waters contain fluoride content ranging between 1.2 to 1.5 ppm (Camargo, 2003).

**Artificial Fluoridation of Water**

The fluoridation of water has often been referred to a great achievement in the 20th century. This is largely because fluoridation of water has become effective in combating dental caries. The first community water fluoridation program was based in the United States in the year 1945. In the late 1960’s several states which include Indianapolis, Philadelphia, New York, San Francisco, Chicago, Detroit and Dallas implemented community water fluoridation (Jones et al., 2005). In the United States, two third of the general population drink water from water systems that are artificially fluoridated to combat dental caries. Despite its effectiveness, it has been argued to be a form of mass medication that is unethical (Gussy et al., 2008).

After the introduction of fluoridated water in the community, dental surgeons in the United States reported a dramatic 60% reduction in dental caries (Erdal & Buchanan, 2005). In 1998 in a paediatric clinic in Boston, in an area with fluoridated water, a study revealed that 69% of the children that were examined had dental fluorosis. Another research conducted in an area of North Carolina where the water is fluoridated showed that 78% prevalence of dental fluorosis while further researchers conducted in areas where there was almost no fluoridation of water showed a prevalence of 3-45% (Erdal & Buchanan, 2005).
Food

Fluoride may be present in various foods consumed by humans. Studies in Canada showed mean fluoride concentrations of 2.118 mg/kg in fish and 0.606 mg/kg in soup (Erdal & Buchanan, 2005). According to Bhat et al. (2015), 65% of the villages in India are exposed to risk of fluoride from food sources. In addition, Bhat et al. (2015) conducted a research in a village close to a smelter to determine the concentration of fluoride in vegetables grown in that area. Bhat et al. (2015) discovered a mean concentration of 0.71 ± 0.90 ppm in vegetables grown very close to the smelter and a mean fluoride concentration of 0.36 ± 0.69 ppm in vegetables grown 10 km from the smelter.

Abugri and Pelig-Ba (2011) showed that sandy soils are known to have low fluoride concentration especially in climates that are humid meanwhile high fluoride concentrations are found in clay soils. In addition, Abugri and Pelig-Ba (2011) also added that some of the common fluoride compounds found in soils include sodium fluoride (NaF), ammonium fluoride (NH₄F), aluminum fluoride (AlF₃), calcium fluoride (CaF₂) and aluminosilicates such as (Al₂(SiF₆)₂).

In Chiang Mai, Thailand, McGrady et al. (2012) concluded that groundwater with high fluoride content that was used for cooking by the people caused severe pitting of the teeth, hypomineralization and the loss of surface enamel. In addition, 98% of the subjects of the research conducted by McGrady et al. (2012) consume rice as a regular meal.
Rice is very common in Thailand and it has the ability to absorb fluoride at the stage of cultivation to the stage of preparation. Buzalef et al. (2001) stated in their research that some cereals are known to contain high concentrations of fluoride. In Brazil, two types of commercially sold cereal products, namely Neston and Mucilon, had considerably high concentration of fluoride (6.2 and 2.44 ppm respectively).

Cooking with fuels rich in fluoride, such as coal, can also result into the intake of fluoride from the prepared meals and through inhalation. In addition, the consumption of tea, which is very common in some parts of Asia, can result into the ingestion of fluoride because of the high fluoride content of tea leaves (WHO, 2010). Studies conducted by Singer et al. (1967), showed different species of tea leaves analyzed in order to determine the fluoride content (Table 3). Research in China showed that there is a respondents showed signs of dental fluorosis despite the fact that the drinking water in the region contains low concentrations of fluoride. The consumption of brick tea containing high fluoride concentrations was responsible for the prevalence of dental fluorosis in the region (Cao, Zhao, & Liu, 1997).

**Table 3.** Fluoride content and percentage of fluoride extracted in tea plants (4-5 min extraction time) (Source: Singer et al., 1967).

<table>
<thead>
<tr>
<th>Tea Plant</th>
<th>Dried leaves ppm F⁻</th>
<th>Extracted in 1st infusion</th>
<th>Unextracted after 4 treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Camellia sinensis Kuntze</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Tea</td>
<td>144</td>
<td>78</td>
<td>3.3</td>
</tr>
<tr>
<td>Green Tea</td>
<td>336</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>Lipton Brisk Tea</td>
<td>161</td>
<td>71</td>
<td>3.0</td>
</tr>
<tr>
<td>Red Owl Orange and Black Tea</td>
<td>144</td>
<td>70</td>
<td>2.3</td>
</tr>
<tr>
<td>Hon Moa Tea</td>
<td>108</td>
<td>69</td>
<td>4.5</td>
</tr>
<tr>
<td>Best Taiwan Tea</td>
<td>52</td>
<td>41</td>
<td>13</td>
</tr>
<tr>
<td><strong>Steuartia koreana</strong></td>
<td>41</td>
<td>29</td>
<td>38</td>
</tr>
<tr>
<td><strong>Steuartia gemmala</strong></td>
<td>95</td>
<td>70</td>
<td>4</td>
</tr>
<tr>
<td><strong>Franklinia alatamaha</strong></td>
<td>21</td>
<td>55</td>
<td>23</td>
</tr>
</tbody>
</table>
Fluoridation of Salt

Fluoridation of salt have been employed in several countries since identification of the effects of fluoride consumption in tackling dental caries. Salt fluoridation programs have been implemented in countries, such as Germany, Switzerland, Czech Republic, Colombia, Jamaica, Cuba and other countries (O’Mullane et al., 2016). In water fluoridation, citizens have little or no option asides from buying bottled water but to drink community fluoridated water. The only advantage that salt fluoridation has over community water fluoridation is the fact that fluoridated salt can be sold alongside non-fluoridated salt. Studies conducted in 1965-1985 in Hungary, Colombia, and Switzerland, showed that the effect of salt fluoridation produced similar results in tackling dental caries compared to water fluoridation (Jones et al., 2005). Since the introduction of salt fluoridation in Costa Rica, there have a 73% reduction in the prevalence of dental caries among 12-year-old children over the period of 15 years (Peterson et al., 2008). Salt fluoridation needs to be regulated especially in places where there are other sources of fluoride. A salt fluoridation program introduced in some Mexican states only allows salt fluoridation where fluoride concentration in water is below 0.7 mg/l (Soto-Rojas et al., 2004). Many countries are implementing such programs however, these programs contribute to the amount of fluoride ingested which might ultimately contribute to development of dental fluorosis.

Fluoridation of Milk

The artificial fluoridation of milk has also become one of the ways through which children receive fluoride at an early age so as to prevent the build-up of dental caries. This technique was first seen in Switzerland and later on spread to other countries.
like Scotland, Hungary, Chile, and China. In Chile, milk-cereal was introduced to ensure that children are taking in enough fluoride to keep them safe from dental caries and in China, fluoridated milk would normally be sent to homes every weekend to ensure adequate fluoride intake (Jones et al., 2005). Research conducted in the United Kingdom by Busell et al. (2016) studied the fluoride content in infant milk and found very low concentration of fluoride in the infant milk widely used. Since the introduction of milk fluoridation in Bangkok, Thailand, in 2000, there has been a 30% decrease in prevalence of dental caries (Peterson et al., 2008). This has encouraged the fluoridation program and could contribute to fluoride intake which could ultimately contribute to development of dental fluorosis.

*Other Fluoridated Products*

Products such as toothpaste, bottled water, soft drinks, fruit juice, cow’s milk, and some beverages contain certain amounts of fluoride (Erdal & Buchanan, 2005). Many soft drinks and fruit juices are commercially prepared with fluoridated water as a result causing them to have significant concentrations of fluoride in them. Toothpaste is another major source of fluoride in the human body especially in children. Sodium fluoride is one of the most active ingredients in majority of the toothpaste produced in recent times. Fluoridation of toothpaste was first introduced in the 1960s and ever since, it has had a major role to play in the reduction in the prevalence of dental caries worldwide. Cows drink water with high fluoride concentration and feed on either grass or some sort of cow feed with high concentration of fluoride, and they ultimately produce milk that has certain concentrations of fluoride. This cow milk goes through further industrial processing
with fluoridated water. Whether fresh or processed, the cow milk will ultimately contain some concentration of fluoride (Erdal & Buchanan, 2005).

**Supplements and Infant Formulas**

Fluoride supplements and infant formulas have long been prescribed for children in areas that are fluoride deficient. These supplements and formulas, however, may contribute to the risk of dental fluorosis in both fluoridated and non-fluoridated areas. Infant formulas that are soy-based have shown to have considerably high fluoride content and this is because of the natural fluoride content of soy extract (Buzalaf et al., 2001).

**Renal Insufficiency**

Renal insufficiency in individuals contribute to increased fluoride levels in the body. Individuals who suffer renal insufficiency have increased chances of suffering from any form of fluorosis (dental and skeletal). Kaminsky et al. (2009) highlighted two cases where patients with renal insufficiency suffering from skeletal fluorosis and atherosclerosis had previously been exposed to water containing fluoride concentration between 2-3 mg/L.

**Malnutrition**

High risk of fluorosis has often been associated with not only presence of fluoride in water but also nutrition of people. Regions where meals have deficiencies in calcium, magnesium, and vitamins were associated with a higher risk of dental fluorosis. According to UNICEF (1999), a regular diet rich in vitamins and calcium can help
reduce risk of dental fluorosis. Massler and Schour (1952) added that intake of low levels of fluoride is harmful to malnourished children.

**Stages of Dental Fluorosis**

Fluorosis is categorized into several levels namely ‘normal’, ‘questionable’, ‘very mild’, ‘mild’, ‘moderate’, and ‘severe’ (Table 4).

**Table 4.** Level of fluorosis according to Dean’s dental fluorosis index (Source: Committee on Fluoride in Drinking Water, National Research Council, 2006).

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (0)</td>
<td>The enamel represents the usually translucent semivitriform type of structure. The surface is smooth, glossy, and usually a pale creamy white color.</td>
</tr>
<tr>
<td>Questionable (0.5)</td>
<td>The enamel discloses slight aberrations from the translucency of normal enamel, ranging from a few white flecks to occasional white spots. This classification is utilized when a definite diagnosis of the mildest form of fluorosis is not warranted and a classification of “normal” is not justified.</td>
</tr>
<tr>
<td>Very mild (1)</td>
<td>Small, opaque, paper white area scattered irregularly over the tooth but not involving as much as approximately 25% of the tooth surface. Frequently included in this classification are teeth showing no more than 1 to 2 mm of white opacity at the tip of the summit of the cusps of the bicuspids or second molars.</td>
</tr>
<tr>
<td>Mild (2)</td>
<td>The white opaque areas in the enamel of the teeth are more extensive but do not involve as much as 50% of the tooth.</td>
</tr>
<tr>
<td>Moderate (3)</td>
<td>All enamel surfaces of the teeth are affected, and surfaces subject to attrition show marked wear. Brown stain is frequently a disfiguring feature.</td>
</tr>
<tr>
<td>Severe (4)</td>
<td>All enamel surfaces are affected and hypoplasia is so marked that the general form of the tooth may be altered. The major diagnostic sign of this classification is the discrete or confluent pitting. Brown stains are widespread and teeth often present a corroded appearance.</td>
</tr>
</tbody>
</table>
Dental Fluorosis Correction

Individuals with fluorosed teeth often seek treatment for this defect so as to restore aesthetic value. For fluorosis-affected individuals, several dental procedures can be employed, such as bleaching, micro or macro abrasion, and veneer lamination (Brown, 2012). To restore the normal coloration of the enamel, the tooth has to undergo a form of bleaching or abrading of the subsurface porosity along with the stains through micro or macro abrasion. Mild cases of dental fluorosis are often treated by bleaching in the dental office or at home (Akpata, 2014). Lee et al. (2005) reported that in the year 2003, the sales of tooth-whitening products that were sold over the counter grew by 57%. The commonly used agents for bleaching are 10% carbamide peroxide and 35% hydrogen peroxide. Micro abrasion techniques often involve the use of hydrochloric acid applied on the area that has been discolored. The hydrochloric acid can be applied alone or sometimes in a pumice mixture (Dazell, Howes, & Hubler, 1995). In cases where there is severe fluorosis and the subsurface
porosity is deep, micro or macro abrasion cannot work because it will destroy the morphology of the tooth hence the need for veneering. In addition, cases where there has been a loss of 50% of the enamel, crowning of the fluorosed tooth/teeth is employed (Akpata, 2014).

**Methods of De-fluoridation**

In areas where fluoride is naturally high in water, different techniques, such as ion-exchange, coagulation-precipitation, nano-filtration, and adsorption, have been employed to reduce the fluoride content to reduce risk of dental fluorosis. Parts of India have employed a technique known as Nalgonda Technique (flocculation of fluoride ions with Alum) in order to reduce fluoride content of water (McGrady et al., 2012).

Parental vigilance is highly recommended for children while brushing their teeth in order to avoid excessive use of toothpaste and in many cases swallowing of toothpaste. Studies conducted in Malaysia showed that 50.7% of 373 children never get supervised by their parents while they brush their teeth (Tay, Zainudin, & Jaafar, 2011). The British Fluoridation Society (2004) advices that parents ensure that their kids apply only pea-sized amount of toothpaste and brush not more than twice a day.

Based on the literature, very few studies about dental fluorosis have been conducted in Nigeria. I am aware of only one study focused on the relationship between dental fluorosis and the concentration of fluoride in water sources. This study was conducted in Jos, Plateau State, north-central Nigeria (El Nadeef & Honkala, 1998). In another study in Borno State, researchers found that fluoride levels were high in
water (Waziri et al., 2012). However, the investigators did not also evaluate the prevalence of fluorosis and social impacts of the defect as part of their study. In Zing, Taraba State, local residents have long been aware of teeth discoloration among its inhabitants. However, this have never been specifically studied in the region. Therefore, I assessed fluoride levels in natural and commercial drinking water sources in Zing LGA to determine the prevalence of dental fluorosis in children who were born in Zing. I also assessed basic social impacts in children with the condition. The study will help raise awareness on dental health and drinking water in north-eastern Nigeria. In addition, I will share my findings with the local communities of Zing, government agencies, public health organizations, and dental societies in Nigeria.
HYPOTHESES AND AIMS & OBJECTIVES

Null Hypothesis ($H_0$): Concentrations of fluoride in water sources in Zing LGA do not exceed WHO permissible limits.

Research Hypothesis ($H_1$): Concentrations of fluoride in water sources in Zing LGA exceed WHO permissible limits.

Research Question: Is there a relationship between the fluoride concentration of drinking water sources in Zing Local Government Area (LGA), Taraba State, eastern Nigeria, and the prevalence of dental fluorosis among children in the community

Aims:

- To investigate the relationship between dental fluorosis in children and fluoride concentration in drinking water sources in Zing Local Government Area (LGA), a rural community in Taraba State, eastern Nigeria
- To access social impacts of dental fluorosis in children

Objectives:

- To identify drinking water sources used by people
- To determine fluoride concentrations in these water sources
- To compare observed fluoride concentrations with international permissible standards
- To identify social or emotional impacts associated with having dental fluorosis as a child
- To determine dental hygiene practices
- To share findings with governmental and non-governmental authorities situated in the area
CHAPTER 2
MATERIALS AND METHODS

Study Area
This study was conducted in Zing Local Government Area, Taraba State, north-eastern Nigeria (Fig. 6). Zing LGA has an area of 1,030 km² and a population of 127,685 at the 2006 census (Nigerian Population Commission, 2007). The dominant tribe in Zing is the Mumuye, which account for 98% of the population. Other tribes include Hausa and Zandi. Majority of local residents are farmers, while some engage in petty trading. According to reports from local authorities, the vast majority of community members are low-income earners who cannot afford personal bore holes that are treated; instead, most residents rely on community bore holes, streams, and wells. Some of the drinking water sources, such as the wells and streams, may be unsafe and untreated.

I conducted this study in March 2017 using both ecological and social research methods.

Data Collection and Analysis

Water Sampling
There are very few natural sources of drinking water in Zing LGA. I first inquired with local authorities and residents about sites where most people obtain drinking water, and then I visited these sites. Using latex gloves and polyethylene containers, I collected 19 water samples from different sources of water (bore holes, streams, wells) from five wards (Anguwan Fada, Anguwan Sarki, Mission ward, Tudun Wada, and Anguwan Lafia) (Table 5), two bottled water samples, and three sachet
water samples. These wards were selected after a short pilot study with 25 local residents (students from the secondary school). Because the majority of the students who responded to the pilot study were born in these wards, I focused my sampling effort on water sources in these wards.
The water samples were analyzed using a Wagtech 7100 Photometer to determine the concentration of fluoride in the samples. The water samples were analyzed within one week of collection in line with recommendations from the United Nations Environment Programme and World Health Organization (Bartram & Ballance, 1996). To compare the fluoride content in these samples with commercially produced and commonly used drinking water sources, such as sachet water and bottled water, I also analyzed two sachet-water samples and two bottled-water samples using the Wagtech 7100 Photometer. I compared my findings with World Health Organization fluoride standards for drinking water, which is generally set at \( \leq 1.5 \, \text{mg/L} \) worldwide, but is \( \leq 1 \, \text{mg/L} \) for tropical regions (WHO, 2011).

**Table 5.** Number of water samples collected from different sources of water in each ward \((n = 19)\).

<table>
<thead>
<tr>
<th></th>
<th>Borehole</th>
<th>Well</th>
<th>Stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anguwan Sarki</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Anguwan Fada</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mission Ward</td>
<td>2</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>Tudun Wada</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Auguwan Lafiya</td>
<td>2</td>
<td>1</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Dental Checks and Questionnaires

In addition to collecting water samples in the local government area, I also collected data at the Government Senior Secondary School-Zing (GSS-Zing). According to the school authority, the population of the school is roughly 1,000 students and 35 teachers. My sampling unit was an individual student. Participants were recruited
based on their age and place of birth. All GSS-Zing students aged 10–17 and who were born in Zing were initially assembled by the senior master of the school on the assembly ground and briefed on the study. For students willing to participate, parental consent was sought at this time.

The study population comprises children because dental fluorosis takes hold in children between the ages of 0 and 8 when the teeth are still developing. Children between the ages of 10 and 17 will either have or not have the condition. I excluded adults as they may have been more likely to try to mask or conceal the condition, by using bleaching agents, etc. In addition, adults may have other habits, such as smoking, that could ultimately affect teeth color. The study is aimed at assessing the prevalence of the defect in children who were born in the community because they would have grown up drinking from local water sources analyzed in this study. These criteria make the sampling unit, sampling strategy, and chosen population appropriate for this research.

I developed structured questionnaires to collect data on demographics, dental hygiene habits, and water and food consumption. These questionnaires were subjected to a pilot test with 25 students. From the pilot test, some questions were removed; some were added; while others were re-written before arriving at the final questionnaire. The questionnaires contained closed- and open-ended questions and were coded for quantitative analysis. The interviews were conducted in a classroom where the students felt comfortable to answer questions. Each student was first subjected to a dental observation by a professional dentist to determine if the student had fluorosis and, if so, what level of fluorosis. After the dental observation, with the
assistance of interpreters, I administered the questionnaire to 135 students, of which
70 were male, and 65 were female. Initially, 150 parental consent forms were
distributed to 150 students, of which 75 were male and 75 were female; however, I
obtained parental consent from 135 students. Each interview took approximately 12
minutes.

Data Analysis

All data were analyzed using IBM Statistical Package for the Social Sciences (SPSS)
version 24. I used descriptive statistics and, for categorical variables, I calculated
cross-tabulations (contingency tables). For the latter, when one or more cells had an
expected frequency of less than 5, I used Fisher’s exact test; otherwise, I used the
Pearson chi-square test. Finally, I used logistic regression to model the effects of
measured variables on the presence/absence of dental fluorosis in children in Zing
LGA. I first evaluated independent variables for multicollinearity (this is when there
is a high degree of correlation among two or more independent variables in a
regression model) using collinear diagnostics in a linear regression. For all
independent variables, no tolerance values were less than 0.10, and no variance
inflation factors exceeded 10 (all were less than 1.5). As there was no clear evidence
of multicollinearity, I retained all predictor variables in the logistic regression
analysis. Using a forward selection process based on likelihood-ratio statistics, a
variable was entered into the model and then evaluated. If the addition of that
predictor variable did not improve the fit of the model, the variable was not retained.
Ethical Guidelines

Prior to this research, I completed the U.S. National Institutes of Health training for “Protecting Human Research Participants” (Certificate: 1894012). In addition, I obtained prior written permission from the school principal at GSS-Zing, consent from parents or guardians, and assent from all participants. This study was approved by the American University of Nigeria Institutional Review Board (Approval Code: AUN-17-02-03).
CHAPTER 3

RESULTS

Description of Respondents

Of the respondents in this study, the mean age was 14.53 years (SD = 1.615, range = 11-17, n=135). Half were male (68; 50.4%), and half were female (67; 49.6%). The wards where the respondents were born and reside include Tudun Wada (36; 26.7%), Mission Ward (29; 21.5%), Anguwan Fada (28; 20.7%), Anguwan Lafia (23; 17.0%) and Anguwan Sarki (19; 14.1%).

Water Analysis

Children in this study drank water from a variety of sources, including wells, boreholes, and streams, as well as from commercially produced water such as bottled and sachet water (Table 7). Most children I interviewed drank water from boreholes, wells, and sachet water.

Drinking water samples collected from 9 of the 10 boreholes had high fluoride concentrations that exceeded the WHO permissible levels ≤ 1.0 mg/L) for tropical regions, in contrast to other drinking water sources (Table 8). The remaining water samples from wells and streams had low fluoride concentration except one well (Table 8). In addition, one sachet water sample had a very high fluoride content.

Dental Checks

More than 80% of respondents had dental fluorosis (111; 82.2%), compared to those with no signs of the condition (24; 17.8%). Most children having fluorosis had mild
Table 6. Frequencies of drinking water sources used by children in Zing LGA.

<table>
<thead>
<tr>
<th>Drink From:</th>
<th>Frequency</th>
<th>Percent (%) of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>47</td>
<td>34.8</td>
</tr>
<tr>
<td>Yes</td>
<td>88</td>
<td>65.2</td>
</tr>
<tr>
<td>Borehole water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>17</td>
<td>12.6</td>
</tr>
<tr>
<td>Yes</td>
<td>118</td>
<td>87.4</td>
</tr>
<tr>
<td>Stream water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>105</td>
<td>77.8</td>
</tr>
<tr>
<td>Yes</td>
<td>30</td>
<td>22.2</td>
</tr>
<tr>
<td>Bottled water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>88</td>
<td>65.2</td>
</tr>
<tr>
<td>Yes</td>
<td>47</td>
<td>34.8</td>
</tr>
<tr>
<td>Sachet water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>14</td>
<td>10.4</td>
</tr>
<tr>
<td>Yes</td>
<td>121</td>
<td>89.6</td>
</tr>
</tbody>
</table>

or very mild cases, while 38 (34%) had moderate or severe cases of the condition. A dentist classified the total number of cases as: questionable (8; 5.9%), very mild (33; 24.4%), mild (32; 23.7%), moderate (19; 14.1%) and severe (19; 14.1%).

Dental Care

The results showed that 127 (94.1 %) of the respondents use a toothbrush, toothpaste, and water to clean their teeth, while the remaining 8 (5.9%) use either a toothbrush and toothpaste, water and chewing stick, or chewing stick only. Out of the 127 respondents that use toothpaste, 19 (14%) use My My, 60 (44.4%) use Close Up, 41 (30.4%) use Oral-B, 5 (3.7%) use Pessodant and 2 (1.5%) use Anchor.
**Table 7.** Fluoride concentration in various water sources tested across different wards.

<table>
<thead>
<tr>
<th>Ward</th>
<th>Source of Drinking water</th>
<th>Fluoride Concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tudun Wada</td>
<td>Borehole 1</td>
<td>2.5*</td>
</tr>
<tr>
<td></td>
<td>Borehole 2</td>
<td>2.6*</td>
</tr>
<tr>
<td></td>
<td>Well</td>
<td>2.5*</td>
</tr>
<tr>
<td></td>
<td>Stream 1</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Stream 2</td>
<td>0.35</td>
</tr>
<tr>
<td>Anguwan Fada</td>
<td>Borehole 1</td>
<td>2.6*</td>
</tr>
<tr>
<td></td>
<td>Borehole 2</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>Well</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Stream</td>
<td>0.24</td>
</tr>
<tr>
<td>Anguwan Sarki</td>
<td>Borehole 1</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Borehole 2</td>
<td>2.6*</td>
</tr>
<tr>
<td></td>
<td>Well</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>Stream</td>
<td>0.45</td>
</tr>
<tr>
<td>Mission Ward</td>
<td>Borehole 1</td>
<td>2.5*</td>
</tr>
<tr>
<td></td>
<td>Borehole 2</td>
<td>2.6*</td>
</tr>
<tr>
<td></td>
<td>Well</td>
<td>0.50</td>
</tr>
<tr>
<td>Anguwan Lafia</td>
<td>Borehole 1</td>
<td>2.8*</td>
</tr>
<tr>
<td></td>
<td>Borehole 2</td>
<td>2.7*</td>
</tr>
<tr>
<td></td>
<td>Well</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Other drinking water sources tested</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eva Bottled Water 1</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>Nanfan Sachet Water</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Stem Sachet Water</td>
<td>2.7*</td>
<td></td>
</tr>
<tr>
<td>Dunama Sachet Water</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>Faro Sachet Water</td>
<td>0.56</td>
<td></td>
</tr>
</tbody>
</table>

*Exceeded WHO permissible limit of 1.0 mg/L for tropical regions.

*Individual Cross-tabulations*

The results of the chi-square and Fisher’s exact tests relating the presence/absence of dental fluorosis and the variables measured in this study indicated that four factors are significantly associated with fluorosis: the ward where a child was born and whether a child drinks from borehole water, stream water, or sachet water (Table 9).
There was no detectable effect due to gender, tooth-brushing method, brand of toothpaste used, and whether the child drank well or bottled water.

There was a significant difference among cases of dental fluorosis and the ward in which children were born in Zing LGA (Table 10). Nearly all children in this study who were born in Tudun Wada and Anguwan Lafia had dental fluorosis.

Table 8. Relationship between predictor variables measured in this study and the presence of dental fluorosis in children in Zing LGA.

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>$\chi^2$</th>
<th>df</th>
<th>p-value</th>
<th>Fisher's Exact p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td>0.261</td>
</tr>
<tr>
<td>Ward Where Born</td>
<td>12.603</td>
<td>4</td>
<td>0.013*</td>
<td></td>
</tr>
<tr>
<td>Well Water</td>
<td></td>
<td></td>
<td>.101</td>
<td></td>
</tr>
<tr>
<td>Borehole</td>
<td></td>
<td></td>
<td>0.000*</td>
<td></td>
</tr>
<tr>
<td>Stream Water</td>
<td></td>
<td></td>
<td>0.000*</td>
<td></td>
</tr>
<tr>
<td>Bottled Water</td>
<td></td>
<td></td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Sachet Water</td>
<td></td>
<td></td>
<td>0.019*</td>
<td></td>
</tr>
<tr>
<td>Tooth brushing Method</td>
<td>1.800</td>
<td>3</td>
<td>0.615</td>
<td></td>
</tr>
<tr>
<td>Brand of Toothpaste</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* = variable is statistically significant at the 0.05 level.
Table 9. Frequencies of cases of dental fluorosis in relation to the ward where a child was born.

<table>
<thead>
<tr>
<th>Ward Where Born</th>
<th>Anguwan Fada</th>
<th>Anguwan Sarki</th>
<th>Tudun Wada</th>
<th>Anguwan Lafia</th>
<th>Mission Ward</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dental Fluorosis</strong></td>
<td>Yes</td>
<td>21</td>
<td>14</td>
<td>33</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>28</td>
<td>19</td>
<td>36</td>
<td>23</td>
<td>29</td>
<td>135</td>
</tr>
<tr>
<td><strong>% of Total</strong></td>
<td>20.7%</td>
<td>14.1%</td>
<td>26.7%</td>
<td>17.0%</td>
<td>21.5%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
**Logistic Regression Modelling**

The logistic regression model identified four variables as important predictors of the presence of dental fluorosis in children in this study. However, due to inflated standard errors of the coefficient estimates for the variable “ward where born,” which is an indication of collinearity, I removed this variable from the model. After doing so, two predictor variables were retained in the final model: drink from stream water and drink from borehole water (Table 11).

Logistic regression modeling showed that the odds of a child having dental fluorosis were higher for those children who drank borehole water compared to those who do not (OR = 8.522). The odds of having fluorosis decreases for children who drink from stream water (OR = 0.203).

<table>
<thead>
<tr>
<th>Step</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>p-value</th>
<th>Exp(B)</th>
<th>95% C.I.for EXP(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Drink From Borehole Water = Yes</td>
<td>2.695</td>
<td>.587</td>
<td>21.114</td>
<td>1</td>
<td>.000</td>
<td>14.808</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>-.741</td>
<td>.293</td>
<td>6.392</td>
<td>1</td>
<td>.011</td>
<td>.476</td>
</tr>
<tr>
<td>2b</td>
<td>Drink From Borehole Water = Yes</td>
<td>2.143</td>
<td>.634</td>
<td>11.419</td>
<td>1</td>
<td>.001</td>
<td>8.522</td>
</tr>
<tr>
<td></td>
<td>Drink From Stream Water = Yes</td>
<td>-1.593</td>
<td>.548</td>
<td>8.432</td>
<td>1</td>
<td>.004</td>
<td>.203</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>-.630</td>
<td>.312</td>
<td>4.065</td>
<td>1</td>
<td>.044</td>
<td>.533</td>
</tr>
</tbody>
</table>

a. Variable(s) entered on step 1: Drink From Borehole Water.

b. Variable(s) entered on step 2: Drink From Stream Water.
Social Impacts

When respondents with fluorosis were asked if they minded their teeth color, 21% expressed unhappiness with their teeth color, while the remaining 79% did not express concern over their teeth. Respondents reported that the condition is traditionally called “zimbo” in this region.
CHAPTER 4

DISCUSSION

Based on the findings from this study, dental fluorosis is common in Zing LGA in Taraba State, north-eastern Nigeria. Considering the results of the water analysis from the different wards in Zing, it was expected that dental fluorosis would be common in the community.

The water analysis showed that 8 out of 10 community boreholes that I tested had fluoride levels higher than the WHO permissible level, while all other sources of water (wells, streams, sachet water, and bottled water) were below this level. There were two exceptions to this: one sachet-water brand (Stem water) and one well sample. Despite that mineral levels in sachet water should be regulated by health agencies, it was not too surprising to discover that Stem water had high fluoride levels compared to other brands (Faro and Nanfam). This is likely because other sachet water products are not produced in Zing, while the Stem water company drilled its source borehole in Zing LGA.

Logistic regression analyses showed that two variables are important predictors of dental fluorosis in children: borehole water and stream water. Children who drink borehole water have a greater probability of developing the condition, while children who drink from stream water have a lower probability. The strength of this relationship was particularly strong for borehole water. These results align with my water sampling results: The boreholes tested in this study were largely highly fluoridated. Ground water occurs as wells, boreholes and springs while surface water occurs as streams, rivers and lakes (Winter, Harvey, Franke, & Alley, 1998). Due to
geologic formations of an area (types of rocks and soils, the porosity and acidity of the rocks and soils), the groundwater will naturally contain more fluoride content compared to surface water (Waziri, Musa, & Hati, 2012). In addition, despite the fact that boreholes and wells are ground water, there is a difference between these two which is the depth at which the water is gotten from. Boreholes are deeper than wells and the depths of different wells could vary as well. The deeper the well, the higher the fluoride concentration in the water because of the intimate contact of the water and the surrounding rocks (Ramanaiah, Venkata, Rajkumar, & Sarma, 2006). This further explains why groundwater contains higher fluoride concentration compared to surface water which has little or no contact with surrounding rocks. Boreholes are In this study, well water was not an important predictor variable, which is not surprising given that only one well had high fluoride levels. I would assume that the well with higher fluoride concentration was deeper than the rest. Although some respondents with fluorosis reported that they drink well water, these individuals reported that they also drink from boreholes. This study did not assess what was a respondent’s major source of drinking water.

Although stream water and borehole water were the most important predictors, individual cross tabulations showed that two other variables may also be important in the development of fluorosis in children. Their exclusion in the final model was likely due to collinearity; however, here I will briefly discuss these variables. In the cross tabulations, there was a statistically significant difference among the wards where the respondents were born and dental fluorosis. More respondents from Tudun Wada had dental fluorosis than respondents from other wards; this is understandable because all the boreholes from Tudun Wada had high fluoride levels compared to the
WHO permissible level, and, as previously noted, the majority of residents get their
drinking water from the community boreholes. In addition, Tudun Wada was the
only ward where a well had a high fluoride content (2.5 mg/L). Both boreholes in
Anguwan Lafia had high fluoride levels; hence, dental fluorosis was also commonly
found in respondents from this ward. Thus, the importance of the ward where
someone is from appears directly related to the borehole water there.

The other variable that was statistically significant in the individual cross tabulations
was sachet water. In this study, the majority of respondents with dental fluorosis also
reported that they drink sachet water, and nearly all respondents (82%) drink sachet
water, which may explain this result. In a community such as Zing, it would be
expected that a large portion of the population would drink sachet water instead of
bottled water given the socioeconomic status of the residents. And as mentioned,
samples tested from the local sachet-water company, Stem, which sources its water
from Zing, had a high fluoride concentration. No bottled water samples I tested were
produced locally in Zing.

Nearly all the respondents (94%) reported that they use a toothbrush, toothpaste, and
water. Of the five toothpaste brands that were used by respondents, all contain
fluoride. Thus, toothpaste is another source of fluoride for these children.

Interestingly, most respondents with dental fluorosis did not say they minded their
teeth color. Given that the respondents in this study live among many others with
this condition, including most of their school peers and friends, having dental
fluorosis does not make them “stand out.” The condition means they look like most
others. Some of the respondents also have parents or other family members with this defect; therefore, they seem to consider it normal. Another factor that may explain why so few respondents did not mind their teeth color is that most of them – about two-thirds – had mild, very mild, or questionable cases of fluorosis. Similarly, in a study on the aesthetic perception of dental fluorosis in Ireland, Brown (2012) found that only respondents with mild, very mild and questionable cases of fluorosis expressed no concern about their teeth.

Not all children in this study were happy about having fluorosis. One 12-year-old male noted, “I don’t smile well because of zimbo.” A female of the same age told me that “The color is not white; it is like chocolate,” while another 12-year-old male student reported that “sometimes I feel somehow when I am in the midst of people that don’t have zimbo”.

**Limitations of Study**

The major limitation was the time available to carry out this study and possibly increase the sample size. Due to the shortage in time, I had to consider a smaller sample size in order for me to be able to complete the study on time. Despite that the results were able to show the relationship between dental fluorosis and drinking water sources, there are other confounding factors that I could not test, such as the nutritional composition of the meals respondents eat; nutrition via food could have an effect on the metabolism of fluoride in the body. In addition, I was not able to test if this defect could be genetic. Although the literature suggests that this defect is mainly associated with drinking water sources, more studies need to be carried out to investigate the genetic basis of this disorder.
Finally, this study would have been benefitted from a control group to show if dental fluorosis occurred in areas with low fluoride content in drinking water. Due to limited time, I was not able to achieve this. This study was not able to access the depth of the wells studied.

**Challenges**

Some of the respondents did not bring back their parental consent forms; therefore, I could not interview them. Despite that the parental consent forms were translated to Hausa for the parents, I had to meet some parents after school to further explain the research. Another challenge came from the respondents who did not want to open their teeth for inspection and needed further convincing.

**Recommendations**

I recommend that the water supply board should test all boreholes in Zing LGA for fluoride content and apply defluoridation techniques that will reduce fluoride content in all the boreholes. I also recommend strict enforcement of policies on water quality especially for water companies that drill their boreholes in Zing LGA. In addition, more studies need to be conducted with larger sample size so as to get a more statistically significant result. I will also advice Zing residents who want to avoid this disorder for the future generation to give their newborn children water from streams, wells, sachet water (not made in Zing), and bottled water. They should limit use of or avoid the borehole water. I also recommend more studies to be conducted so as to determine if there any relationship between dental fluorosis and genetics. In addition, children with moderate to severe levels of dental fluorosis should visit a dentist for dental counseling.
CHAPTER 5

CONCLUSION

Dental fluorosis is a defect that has not been studied well in Nigeria. This defect is very common in Zing LGA of Taraba state, northeastern Nigeria. Majority of the respondents in this study had this defect. This defect is so common that it has become a norm in the community. This results from this study supported my hypothesis, drinking water sources in Zing LGA have high fluoride content especially boreholes and there was a statistically significant relationship between dental fluorosis and borehole water. Other variables like gender, well water and stream had no relationship with dental fluorosis. In order to prevent this defect for the future generation, there should be frequent testing of the various water sources in this area and the water board supply has to apply defluoridation in order to defluoridated the water containing high fluoride concentration. Community awareness needs to be raised concerning the fluoride levels in the boreholes so as to enable residents know the cause of dental fluorosis in the community.
Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that Gwaha Madwatte successfully completed the NIH Web-based training course “Protecting Human Research Participants”.

Date of completion: 10/18/2015

Certification Number: 1894012
APPENDIX II

DENTAL FLUOROSIS IN A RURAL NIGERIAN COMMUNITY: IS THE WATER TO BLAME?

Dentist’s Observation

1. Does this person have fluorosis?
   Yes [ ]                No [ ]

If yes, what level of fluorosis does he/she have?
0 [ ]    0.5 [ ]    1 [ ]    2 [ ]    3 [ ]    4 [ ]

Demographic Data

2. Age (In years) ___________
3. Sex
   Male [ ]                Female [ ]
4. Which area in Zing were you born?
   Anguwan Fada [ ]        Anguwan Sarki [ ]        Tudun Wada [ ]        Anguwan Lafia [ ]
   Mission ward [ ]

Water Consumption

5. What do you get your drinking water from?
   Well [ ]                Bore hole [ ]                Stream [ ]                Bottled Water [ ]                Sachet Water [ ]

Hygiene and Habits

6. What do you use to brush your teeth
   Toothbrush and water only [ ]    Toothbrush and toothpaste and water [ ]
   Chewing stick only [ ]    Toothbrush and water and chewing stick [ ]
7. What is the name of tooth paste you use?
________________________________________________________________________

8. When last did you brush your teeth?
   Yesterday [ ]      Today [ ]            Day before yesterday [ ]

Fluorosis

If person has fluorosis

9. Do you mind your teeth color?
   Yes [ ]         No [ ]

If yes, please explain why:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
REFERENCES


Cao, J., Zhao, Y., & Liu, J. (1997). Brick Tea Consumption as the Cause of Dental Fluorosis among Children from Mongol, Kazak and Yugu populations in China. *Food and Chemical Toxicology, 35*, 827-833.


