PREVALENCE OF DENTAL FLUOROSIS AND CONCENTRATION OF FLUORIDE IN DRINKING WATER AT SUMBRUNGU IN THE BOLGATANGA METROPOLIS.

By

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A Thesis submitted to the Department of Environmental Science,

Kwame Nkrumah University of Science and Technology, in partial fulfilment

of the requirement for the degree

Of

MASTER OF SCIENCE (ENVIRONMENTAL SCIENCE)

Faculty of Bioscience, College of Science

JUNE, 2012

DECLARATION

I, Enoch Edusei do hereby declare that this thesis is my own work towards the MSc(Environmental Science) degree and that, it contains no material previously published by another person nor material which has been accepted for the award of any degree, except where due acknowledgement has been made in text.

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DEDICATION

This work is dedicated to my sweet grandmother, Mrs. Georgina Martha Edusei, for all her struggle and toil in bringing me to this level. I also dedicate it to my lovely mother, Dorothy Duku for her support and prayer. To my sister, Mrs. Emma Ampofo for her care and support and to my unborn Niece and finally to Daniella Asare Bekoe for her love, support and prayer.

You form a great and united team of which I am proud to be part.

ACKNOWLEDGEMENT

I thank the Almighty God, whom I serve, for the grace given me to finish this thesis. I feel a deep sense of gratitude to my supervisor, Prof. K. Obiri-Danso for his patience, guidance and inputs without which this study would not have been a success.

My gratitude also goes to Mr. Washington, technician at the Chemistry Department, KNUST. I also owe a debt of immense gratitude for the assistance offered me by Mr. Michael and Mr. Richard Atibila from Bolgatanga District Assembly. I am highly indebted to my entire family for their endless love, inspiration and encouragement I also owe a debt of gratitude to my friends for their moral support, I say big thanks to all of you.

ABSTRACT

The prevalence and severity of dental fluorosis in children between the ages of 12 and 15 years, who were born and live in Sumbrungu, Bolgatanga metropolis, was determined between December 2011 and February 2012, The study also determined the concentration of fluorides (F-) using the fluoride specific ion selective electrode method. Additionally, dental fluorosis amongst the children was determined according to the Dean's fluorosis Index. To determine the severity of fluorosis, the Community Fluorosis Index (CFI) was calculated. Mean concentration of fluoride was highest 1.06±0.14 in boreholes, followed by wells 0.99±0.11and lowest 0.37±0.08 in surface waters. However, fluoride concentration in all the different water sources; boreholes, wells and river at Sumbrungu were statistically not significantly different. Prevalence of dental fluorosis in the Sumbrungu community was 65% and the Community Fluorosis Index, 1.3. Thus even though fluoride concentration in the different water sources is lower than the WHO guideline, the Community Fluorosis Index is higher than 0.6 which indicates a public health problem.

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CHAPTER ONE

INTRODUCTION

1.1 Background Information

Fluorine is the most electronegative of all chemical elements and is therefore never found in nature in elemental form. Combined chemically in the form of fluorides, it ranks seventeenth in abundance of elements in the earth's crust representing about 0.06-0.09% of the earth's crust (WHO, 1994). It occurs in a combined form as fluorides in rocks and soil in a wide variety of minerals such as fluorspar or fluorite, cryolite apatite, pegmatites such as tourmaline and topaz (Buxton and Shernoff, 1999). Owing to the universal presence of fluorides in earth's crust, all water contains fluorides in varying concentrations ranging from trace levels to several milligrams per litre (WHO, 1994).In surface fresh water such as rivers and lakes, fluoride concentrations are usually low, ranging from 0.01 to 0.3 mg/L (Murray, 1986). However, exceptionally higher values can be found such that some lakes in Kenya have fluoride content greater than 2000 mg/L. For example, Lake Nakuru, which is situated in the rift valley in Kenya, has a fluoride concentration of 2800 mg/L (Murray, 1986) and it is reported that this is the highest natural fluoride concentration ever found in water.

Unsatisfactory water supplies can result in poor human health. This portends the fact that there are very strong links between water and health (WHO, 1984) and it is through water that fluoride, which is an essential trace element for the human body is ingested (Apambire *et al.*, 1997).Interest in the fluoride content of water stems from its public health importance as fluoride is beneficial in small amounts but toxic in large amounts. Small amounts in ingested water are usually considered good to have a beneficial effect on the rate of occurrence of dental caries, particularly among children. On the other hand due to its strong electronegativity, fluoride is attracted by positively charged calcium ions in teeth and bones (Udom *et al*, 2002).

Consumption of water with fluoride concentration of less than 0.5mg/L in drinking water leads to dental carries while fluoride content of between 0.5 to 1.5mg/L promotes dental health (WHO, 1984). A fluoride content of 1.5 to 4mg/L in drinking water leads to dental fluorosis while concentrations of greater than 4mg/L leads to dental, skeletal and crippling fluorosis.

Dental fluorosis refers to a set of defects of the enamel associated with hypoplasia or hypomineralization of dental enamel and dentine as a result of excessive ingestion of fluoride during the critical period of tooth formation. The distribution is generally symmetrical and bilateral in the surface of the enamel (Vazquez-Alvarado *et al*. 2010). Dental fluorosis is the most common manifestation of chronic use of high fluoride water and it has greatest impact on the growing teeth and children are particularly vulnerable (Murray, 1986).

Dental fluorosis ranges from barely perceptible striations in the enamel to severe pitting and subsequent staining. Consequently, its cosmetic significance depends upon its severity. North American studies, which confined their estimates to children who were life-long residents of fluoridated and non-fluoridated communities respectively, reported prevalence rates of 20 to 75% for the former and 12 to 45% for the latter. European studies reported ranges of 54 to 79% and 14 to 36%, respectively. Studies from Mexico and Brazil reported rates of 61 to 64% and 31 to 50%, respectively (Lewis and Banting, 1994). A high concentration of fluoride coupled with a high prevalence of dental fluorosis affects some of these communities, for example a survey conducted by the Ghana Health Service in 1995 indicated that about 62% of the children in Bongo Central suffer from the disease. Due to the high prevalence of fluorosis the sources of drinking water such as the boreholes and wells have been caped due to the presence of high concentration of fluoride. This makes water scarce in these areas.

Excessive fluoride intake also causes, cancer, arthritis, and affects human intelligence, especially in children, who are most susceptible to early fluoride toxicity (Li *et al*., 1995).

1.2 Problem Statement

Clean water is a priceless and limited resource that man has began to treasure only recently after decades of pollution and waste (Silderberg, 1996). Potable water is an essential ingredient for good health and the socio-economic development of man (Udom *et al*., 2002), but it is lacking in many societies. Contaminants such as bacteria, viruses, heavy metals, nitrates, fluorides and salts have polluted water supplies (Singh and Mosley, 2003)

Availability of potable drinking water is a major problem in most places in Ghana, especially in the Northern regions of the country. Sumbrungu is a town in the Bolgatanga metropolis where potable water is scarce; most of them resort to other sources of water such as hand dug wells, boreholes and rivers. Rocks in Northern Ghana are mainly Granites and some Birimian rocks which are known to have high concentration of fluoride (Smedley *et al*., 1995) apart from this Sumbrungu experiences high mean temperatures of 31°C .These high mean temperatures can lead to a high consumption of water, which might contain a high concentration of fluoride. The presence of fluoride bearing minerals, high mean temperatures which will lead to an increased consumption of water containing fluoride might lead to a high prevalence of dental fluorosis.

1.3 Justification

Seventy percent of the Ghanaian population lives in the rural areas. In these areas, water from boreholes and wells is being increasingly used for domestic and livestock consumption. In all the ten regions of the country, borehole and well water constitutes the greater part of the public water supply systems (Antwi, 1995). Awareness of the quality of drinking water is also lacking among the rural population, which usually has no 'provider' of drinking water. Since fluoride in water constitutes the main dietary fluoride for man and livestock, there is the need to know the levels of fluoride in drinking water. UNICEF, (2006) stated that achieving the millennium Development Goal and its 2015 targets of reducing by half the proportion of people without sustainable access to safe drinking water and sanitation are of vital relevance. Drinking safe water has therefore become a matter of high priority to national agencies, environmentalists and medical practitioners.

For the Upper East region, this is an interesting study site for this work as the rocks are mainly Granites and some Birimian rocks which are known to have high concentration of fluoride (Smedley *et al*., 1995). According to World Health Organization Report 2006, it is particularly important to consider climatic conditions, volume of water intake and other factors when setting national standards for fluoride.

The 1.5 mg/L guideline value of WHO is not a "fixed" value but is intended to be adapted to take account of local conditions (WHO, 2006) and Ghana is not an exemption. This study therefore aims at assessing the concentrations of flouride in drinking water as well as the prevalence of dental fluorosis. This study will provide data which will help determine whether the standard set by Ghana is the best considering the mean temperature. This would provide the basis for future debate on revising the standard for fluoride in water and fluoridation of the public water supply system to control dental fluorosis in Sumbrungu. It will also provide information that will help decision makers take corrective actions with minimal negative impacts on population health. The routine monitoring of water can assure the populace that the quality of their drinking water is adequate. The findings can then be used as a basis for improving the water quality and also provide potable water for this community whilst reducing the prevalence of dental fluorosis.

1.4 Objectives

1.4.1 General

- To determine the fluoride concentration of drinking water (hand–dug wells, boreholes and surface waters) and prevalence of dental fluorosis at Sumbrungu in the Bolgatanga Metropolis.

1.4.2 Specific Objectives

- To determine the concentration of fluoride in borehole water sources in Sumbrungu.
- To determine the concentration of fluoride in hand-dug wells.
- To determine the concentration of fluoride in surface water.
- To determine the prevalence and severity of fluorosis among 12-15 year old Sumbrungu children.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Sources of water

Water resources are sources of water that are useful or potentially useful. Ninety-seven percent of the water on the earth is salt water, only three percent is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps (USGS, 2009). The remaining unfrozen fresh water is found mainly as groundwater, with only a small fraction present above ground or in the air (Molden, 2007).

Drinking water comes from surface water and ground water. Large-scale water supply systems tend to rely on surface water resources, and smaller water systems tend to use ground water. The Environmental protection Agency (EPA) Ghana, 1995 estimated that fresh water resources of Ghana amount to about 40 million-acres and these are derived from the following sources: rainfall, rivers, streams, springs, lakes and groundwater from various aquifers.

Surface water includes rivers, lakes, and reservoirs. Surface water may be readily available and easy to abstract, but is typically polluted . Ground water is pumped from wells that are drilled into aquifers. Aquifers are geologic formations that contain water. The quantity of water in an aquifer and the water produced by a well depend on the nature of the rock, sand, or soil in the aquifer where the well withdraws water. Drinking water wells may be shallow; 50 feet or less or deep; more than 1,000 feet (USGS, 1996).

According to USGS Circular 1139, a public water system may use one or more source water types for drinking water. These source water types include: Surface water source which is any “untreated” water source that is diverted directly from a stream, river, lake, pond or similar surface water body. Ground water source which is any “untreated” water source that is diverted directly from an underground source of water (i.e., an aquifer). Ground water source under the direct influence of surface water - any “untreated,” shallow ground water source that testing has shown to be in hydrologic connection to a nearby surface water body.

There are three different categories of public water systems. The SWAP program evaluated the following types of public water systems: Community systems which primarily serve the homes of year-round residential customers (such as city water systems); Non-Transient, Non-Community systems which serve a relatively stable group of non-residential customers (such as schools and factories with their own water systems); and Transient, Non-Community systems which serve a changing population group (such as camp grounds, rest areas and truck stops with their own water systems).

Water is continually moving around, through, and above the Earth. It moves as water vapor, liquid water, and ice. It is constantly changing its form. The quality of water is identified in terms of its physical, chemical and biological parameters (Sargaonkar and Deshpande, 2003).

2.1.1 Groundwater

Groundwater refers to any subsurface water that occurs beneath the water table in soil and other geologic forms. Scientists estimate that groundwater makes up 95% of all freshwater available for drinking. Some water underlies the Earth's surface almost everywhere, beneath hills, mountains, plains, and deserts. It is not always accessible, or fresh enough for use without treatment, and it's sometimes difficult to locate or to measure and describe. This water may occur close to the land surface, as in a marsh, or it may lay many hundreds of feet below the surface, as in some arid areas of the West. Water at very shallow depths might be just a few hours old; at moderate depth, it may be

100 years old; and at great depth or after having flowed long distances from places of entry, water may be several thousands of years old (Bruno,2006).

Generally, groundwater is renewed only during a part of each year, but can be abstracted year-round. Provided that there is adequate replenishment, and that the source is protected from pollution, groundwater can be abstracted indefinitely. (Struckmeier et al, 2005). Where it is extracted with reasonable ease, groundwater is normally preferable to surface water because it is purified by the filtering action of the soil through which it flows. Nevertheless, groundwater in some areas contain iron, manganese, salts, fluoride or other substances which makes it undesirable or pleasant (Falvey,1999).

As a result of immense industrialization and high population growth, groundwater is heavily relied on throughout the world to serve as an alternative source of water where surface water is seriously polluted. The continued reliance on ground water has resulted in its decline in quantity and quality.

Fluoride has been known to be found most frequently in groundwater at higher concentrations, depending on the nature of rocks and the natural flouride-carting minerals at certain depths. Thus high fluoride concentrations generally can be expected from calcium-poor aquifers and where cation exchange of sodium for calcium occurs (Cairncross and Feachem, 1991). Most groundwater sources have higher fluoride concentrations than surface water. As groundwater percolates through the weathered rock in the aquifers, it dissolves fluoride bearing minerals hence releasing fluoride into solution (Falvey, 1999). The concentration of fluoride in groundwater is varied and depends on the geological formations traversed by water, temperature, pH, solubility of fluoride bearing minerals and the presence or absence of other precipitating or complexing ions (Parkhurst *et al*, 1996). Because of the large number of variables, the fluoride concentrations in groundwater can range from well under 1 mg/L to more than 35 mg/L (WHO, 1994). Many studies have reported the occurrence of high fluoride ground waters in some parts of the world (Murray, 1986). One of the countries, which have been affected severely, is India, where fluoride concentrations of up to 38.5 mg/L have been reported. According to the Survey of the Status of Drinking Water Supply in Rural Habitation, conducted by the Rajiv Gandhi National Drinking Water Mission, there are about 9741 villages that have groundwater sources with fluoride contents of more than 1.5 mg/L (Agrawal, 1997). High fluoride groundwater has also been reported in Mexico . In Guadiana Valley, drinking water supply is obtained from underground wells and is characterized by a high content of fluoride. Hurtado et.al (2005) reported that in Los Altos de Jalisco, situated in central Mexico, communities use water with a fluoride concentration of up to 12.97mg/L. Agrawal (1997) reports that in Sri Lanka, fluoride has a strong geographical control linked to climatic conditions, with high fluoride waters being restricted to the dry zone on the eastern side of the island.

2.1.2 Boreholes

Water occurs under pressure in a well confined aquifer and once a borehole is drilled water rises up through the hole under pressure. Often a borehole will be drilled to a depth of 100m or more. Once a critical layer of the water is met, the water rises sometimes to within a few meters of the surface (Feachem *et al*., 1983). If the water comes to the surface under pressure it is known as free flowing or artesian borehole. The infiltration of water through permeable ground will be halted where an impermeable material like clay is formed well above the ground water table.

The contribution of groundwater to the total water supply is greatest in arid and semi arid region and in some places where geological conditions favour groundwater storage (Thomas and Luna, 1978).Although groundwater especially from deep sources are considered free of contamination, some study (Rogbesan *et al.*, 2002) have found that water from boreholes do not meet the WHO standard for drinking water. This gives credence to the fact that no water is 99% pure (Cabelli, 2003)

Good well design is important in the prevention of underground water pollution. During the construction process of a borehole, drilling fluids, chemical casings and other materials may find their way into the well thereby polluting the water. An open hole during the construction stage can also be direct route for contamination when there is a lengthy delay in completing the well. Even if no sources of anthropogenic contamination exist, there is potential for natural levels of metals and the other chemicals to be harmful to human health. This was highlighted in Bangladesh where natural levels of arsenic in groundwater were found to be causing harmful effects on the population (Anawara *et al*., 2002). Unfortunately, this problem arose because the groundwater was extracted for drinking without a detailed chemical investigation. Monitoring the quality of water is very essential for environmental safety. The natural water analyses for physical and chemical properties including trace elements contents are very important for public health studies (Kot *et al*., 2000).

Drilling a borehole makes it possible to reach deep aquifers that are less likely to be affected by pollutants originating from the land or surface water. Natural fluoride in water is derived from the solvent action of water on the rocks and soils of the earth's crust. Fluoride concentration of natural waters therefore depends, among other things, on the solubility of fluoride-containing mineral in the underground water and the porosity of the rocks and soil through which the water passes (Smith, 1983).

In Malawi, the Ministry of Health and Population reports that a survey was carried out in Machinga on occurrence of high fluoride ground water (MOH, 1996; Sibale *et al.*, 1998).

A few boreholes were sampled for fluoride determination in Machinga where fluoride content in water sources was as high as 8.6 mg/L (Sibale *et al.*, 1998). In Nkhota Kota District, an area lying in the rift valley, water from hot springs has a fluoride content of up to about 17 mg/L and Chikwidzi spring is about 8 mg/L (Chapusa and Harrison, 1975).

2.1.3 Hand dug well

A well is an excavation or structure created in the ground by digging, driving, boring or drilling to access groundwater in underground aquifers. The well water is drawn by an electric submersible pump, a trash pump, a vertical turbine pump, a hand pump or a mechanical pump. It can also be drawn up using containers, such as buckets that are raised mechanically or by hand.

There are different types of wells ranging from hand dug wells to drilled wells. Hacking at the ground with a pick and shovel is one way to dig a well. If the ground is soft and the water table is shallow, then dug wells can work. Historically, dug wells were excavated by hand shovel to below the water table until incoming water exceeded the digger's bailing rate. The well was lined with stones, brick, tile, or other material to prevent collapse, and was covered with a cap of wood, stone, or concrete.

Wells can vary greatly in depth, water volume and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water by removing minerals such as arsenic, iron and manganese. Agrawal (1997) reports that in Sri Lanka, fluoride has a strong geographical control linked to climatic conditions, with high fluoride waters being restricted to the dry zone on the eastern side of the island.

2.1.4 Surface water

Surface water refers to water occurring in lakes, rivers, streams, or other fresh water sources used for drinking water supplies. Water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and sub-surface seepage. Surface waters are generally easier to abstract than groundwater.

Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water lost.

Owing to the universal presence of fluorides in earth's crust, all water contains fluorides in varying concentrations ranging from trace levels to several milligrams per litre (WHO, 1994). In surface fresh water such as rivers and lakes, fluoride concentrations are usually low, ranging from 0.01 to 0.3 mg/L (Murray, 1986). However, exceptionally higher values can be found such that some lakes in Kenya have fluoride content greater than 2000 mg/L. For example, Lake Nakuru, which is situated in the rift valley in Kenya, has a fluoride concentration of 2800 mg/L (Murray, 1986) and it is reported that this is the highest natural fluoride concentration ever found in water.

2.2 Fluoride

Fluorine is the most electronegative of all chemical elements and is therefore never found in nature in elemental form. Fluorine (F) is the most reactive and the most electronegative nonmetal and therefore almost never occurs in nature in its elemental state and mainly found in ground water resulting from the reaction of water with rocks and the soil of the Earth's crust (Chadha *et al.*,1999). Fluoride exists in a number of minerals among which fluorspar; cryolite and fluorapatite are the most common. Fluoride is an essential trace element for human body and ingestion mainly takes place through drinking water (Apambire *et al*., (1997). Combined chemically in the form of fluorides, it ranks seventeenth in abundance of elements in the earth's crust representing about 0.06-0.09% of the earth's crust (WHO, 1994).

It occurs in a combined form as fluorides in rocks and soil in a wide variety of minerals such as fluorspar (fluorite) (CaF_2), cryolite (Na_3AlF_6), apatite ($Ca_5(PO_4)_3F$), pegmatites such as tourmaline $Na(Mg, Fe, Li, Al, Mn)_3Al_6(BO_3)_3Si6O_{18}(OH,F)_4$ and topaz $Al_2SiO_4(F,OH)_2$ (Buxton and Shernoff, 1999; WHO, 1994; Hamilton *et al*., 1982). During formation and in the presence of fluoride ions, the fluoride can substitute the hydroxide ion (OH-) in certain minerals such as muscovite ($K_2Al_4(Si_6Al_2O_{20})(OH,F)_4$ which is in the mica group and amphiboles such as amosite $(FeMg)_7(Si_4O_{11})_2(OH)_4$ and also in hornblende $(Ca,Na)_{2\text{-}3}(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH)_2$ (Hurtado *et al.*, 2000;Fleischer and Robinson, 1963).Flouride is commonly associated with volcanic activity and gases emitted from the earth's crust. Thermal water, especially those of high pH are also rich in flouride. Flouride has various uses in many industries including toothpaste, ceramics, tiles, bricks, etc. Fluoride is present in water, food and air. Flouride is not found naturally in the air in large quantities. Average concentrations are found in groundwater due to the presence of flouride bearing minerals. Average flouride concentration in seawater is approximately 1.3mg/L. As for food it has been shown that vegetables and fruits have low levels of flouride with ranges of 0.1-0.4mg/kg (WHO, 2004.)

In one study that was done, it was shown that 34% of the flouride in black tea remains in the oral cavity (Simpson *et al*., 2001).Toothpaste contains very high concentration of flouride up to 1000-1500mg/kg of toothpaste, however what is accidentally swallowed and ingested may range from up to 3.5mg/day. It has been shown that with all the human exposure to flouride that varies from region to region, drinking –water is generally on average the largest single contributor to daily flouride intake (Murray, 1986).Due to this fact, daily flouride intake (mg/kg of body weight) are based on flouride levels in the water and water consumption per day per liter.

Flouride is a chemical element that has shown to cause significant effects on human health through drinking water. Different forms of flouride exposure are of importance and have been shown to affect the body's flouride content and thus increasing the risks of flouride-prone diseases.

Fluoride is known to enter the body through drinking water, food and air. Drinking water constitutes the most significant source of transmission into the body, whiles adsorption through the skin is common in industrial environments even though this may be in low concentrations.

2.3 Presence of fluoride in water

As per WHO (1993) permissible limit for fluoride in drinking water is 1.0 mg/l, whereas USPHS (1962) has set a range of allowable concentrations for fluoride in drinking water for a region depending on its climatic conditions, because the amount of water consumed and consequently the amount of fluoride ingested being influenced primarily by the air temperature (Heyroth, 1953). Accordingly, the maximum allowable concentration for fluoride in drinking water in Indian conditions comes to 1.4 mg/l, while as per Indian standards it is 1.5 mg/l (BIS, 1991).

The fluoride content in the groundwater is a function of many factors such as availability and solubility of fluoride minerals, velocity of flowing water, temperature, pH, concentration of calcium and bicarbonate ions in water, etc. (Chandra *et al*., 1981).

Apambire *et al*., (1997) have suggested that the main sources of groundwater fluoride in granitic rocks are the dissolution and anion exchange with micaceous minerals and their clay products.

2.4 Optimal level of water fluoridation.

Villa *et al.*, (1996) examined children from five cities in Chile where the fluoride concentration in the water supply ranged from 0.07 ppm to 1.10 ppm. All were located within a temperate climatic zone. The data suggested that 0.5-0.6 ppm was optimal in terms of reductions in the prevalence of fluorosis. However, these data may not be generalizable to other populations.

In 1991, the National Health and Medical Research Council of Australia used historical data to estimate that caries rates would increase by 10 to 15% overall if water fluoride concentrations were reduced from 1.00 ppm to 0.5 ppm. However, along with the studies on the discontinuation of water fluoridation, the studies by Heller *et al*., (1997) and Villa *et al*., (1996) suggest that reducing levels of fluoride in the water would not necessarily result in marked increases in caries rates in child populations. Since total fluoride intake is higher than in the 1940s when the first standards regarding optimal fluoride concentrations were first specified (Ismail, 1996), further research regarding the effectiveness of reduced levels of fluoride in the water supply is needed.

The original recommendation of 1 ppm was an arbitrary standard developed by Dean in the mid-1930's based on his judgment that the degree of fluorosis associated with fluoride concentrations below this level was of no public health significance. This was subsequently expanded to the range 0.7 to 1.2 ppm according to the mean annual temperature of the community in question and variations in water consumption patterns that were observed as a consequence of climatic differences. The standard 1.0 to 1.2 ppm for temperate climates is in place today (Burt and Eklund, 1999).

Ismail (1996) has suggested that there is a need for new guidelines regarding levels of fluoride in the water supply. The amount recommended for each community should be based on the prevalence of caries and fluorosis in each community, exposure to other sources of fluoride and the prospects for reducing exposure to discretionary sources. The values of the community in terms of the trade-off between reductions in caries and increases in fluorosis also need to be considered. Relatively high levels of fluorosis might have been acceptable forty years ago when reductions in caries of 10 or more tooth surfaces were being achieved, but may not be acceptable in an era in which reductions in decay of only 1 tooth surface can be expected. Burt and Eklund (1999) suggest that fluorosis may well emerge as a public health problem as technologies for treating cosmetic defects are developed and marketed by the dental profession.

The limited information that is currently available suggests that there is no longer one fixed concentration that can be considered effective. Ismail (1996) suggests that a range from 0.5 to 1.2 ppm is more appropriate since it can be adapted in the light of local needs. However, it is increasingly unlikely, given access to other sources of fluorides, that concentrations at the upper end of this range would be necessary in contemporary North

American populations. Ismail (1996) has also suggested that since fluoride is available from a number of sources, the absence of water fluoridation does not mean that the population is not exposed to levels of fluoride effective in terms of reducing dental decay. Rather, water fluoridation should be targeted to areas where the prevalence of decay is unacceptably high. This conforms to the recent observation by Rozier (1994) that an emerging body of professional opinion is claiming that not all communities need to be fluoridated. Moreover, since even mild forms of dental fluorosis may well emerge as a public health problem, fluoride intake during the period of susceptibility should be kept as low as possible. Concentrations of 0.5-0.6 ppm may well be sufficient to bring about meaningful reductions in dental decay while avoiding the development of fluorosis in many individuals. The aim of public health interventions such as water fluoridation should not be to reduce dental decay but to maximize the oral health-related quality of life of the population as a whole. This involves making trade-offs between dental decay and fluorosis and also further consideration of the so-called social equity aspect of fluoridation programs. A careful balancing of the interests of majority and minority populations is necessary if a community wide intervention such as water fluoridation is to be ethically and politically acceptable.

2.5 Water Defluoridation

Before drinking water with high concentration of fluoride, treatment of these waters is necessary in order to eliminate any negative effects on the mass population. Three specific treatments have been deemed successful in the removal of fluoride from drinking water. These processes are shown in table below;

Table 2.1: Water Defluoridation

	Coagulation	Activated Alumina	Membranes
Flouride removal	50% or more	80% or more(<1mg/L)	80% or more(<mg//L)

Source: Farewell *et al*., 2006

2.5.1 Coagulation

Chemical coagulation is a treatment process commonly used for surface water. In this process the chemical coagulant which is usually aluminum or iron salts, are placed in the raw water under specific dosages and conditions to form a solid flocculants or flakes that may be easily filtered from the water.(Farewell et al.,2006).The precipitated floc removes the dissolved fluoride contaminant by charge neutralization, adsorption and entrapment. This process is also known as the Nalgonda process that was developed for low-income African households (Farewell et al.,2006).This process will remove fluoride up to 50% and possibly more depending on the nature and the degree of the fluoride content in the water (Farewell et al.,2006).

2.5.2 Activated Alumina

Activated alumina is used in a treatment process to filter flouride in drinking water. It is made of aluminum oxide and has a very high surface area to weight ratio allowing it to have many small pores that run through it (Farewell et al., 2006).

2.5.3 Membrane process

The most significant processes in water treatment for membrane processes include reverse osmosis, ultra –filtration, micro-filtration and nano-filtration (Farewell et al.,2006).These processes are now recently being applied to the treatment of drinking water. Membrane operations generally utilize artificial membranes to separate the mixtures and capture the undesired material. This process is successful in fluoride removal from drinking water up to 80% or more, leaving the water with a fluoride content of less than 1mg/L (Farewell *et al*., 2006).

2.5.4 Other De-fluoridation Technologies

Other forms of de-fluoridation include calcined clay and bone charcoal. Calcined clay includes clay powder and fired clay which is capable of sorption of fluoride along with other contaminants in water. Clay has the ability to clear the turbidity of water, which is a quality that is believed to have been used in domestic households in ancient Egypt (Farewell *et al*., 2006). Even though clay soaks up fluoride in the form of sorption, however it may also be utilized as a flocculent powder causing precipitate that may later be filtered out (Farewell *et al*.,2006).As for bone charcoal the process entails a material (bone charcoal) which is a blackish, granular materials composed of Calcium phosphate, Calcium carbonate and activated carbon. When in water, the bone charcoal is capable of absorbing a wide range of pollutants including fluoride (Farewell *et al*., 2006).However bone charcoal in some cultures originates from pigs and thus may be questioned by Muslims as well as Hindus and Jews (Farewell *et al*., 2006).Some villages in North Thailand oppose the charring of bones and thus may also have stipulations with respect to this de-fluoridation process. When considering different methods and technologies of de-fluoridation, it is important to consider these cultural and religious factors, as well as considering cost, material availability locally and feasibility of technology in that region of the world.

2.6 Drinking Water Standards

There are maximum guiding values for flouride in drinking water. There are no minimum imposed limits, however there are recommended values to ensure no potential health risks from lack of flouride within the drinking water. World health organization (WHO) places international standards on drinking water that should be adhered to for health purposes, however is not enforceable and each individual nation may place its own standards and conditions on the drinking water. This can be seen in the United States, where the environmental Protection Agency (EPA), the regulatory body for the drinking water places more lenient drinking water standards than that of WHO. This can be seen in table 2.2

Table 2.2: Drinking water standards internationally and nationally

Flouride Guideline Value Drinking water standards	Recommended Minimum Value(mg/L)	Maximum Value(mg/L)	Reference
WHO	0.5	1.5	WHO(1993)
USA-Primary Secondary	0.5 0.5	4.0 2.0	US EPA(1985)
Egypt	-	0.8	Egypt-Decree 108 and 301/1995(1995)
Jordan	-	2.0	Jordan(2001)
Morocco	-	0.7	Morocco(1991)
Kuwait	0.5	1.5	WHO guidelines applies without modifications
Palestine	0.6	1.0	Palestine(1997)
Saudi Arabia	0.7	1.2	Saudi Arabia(2000)
Lebanon(at8-12°C) (at 25-30°C)	-	1.5 0.7	Lebanon(1996)
Iraq	-	1.0	Iraq(2001)

Primary Drinking water standards are those that must be enforced. Secondary Drinking water standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects such as skin to tooth discoloration or aesthetic effects such as taste, odor or colour in drinking water (US EPA, 1985). EPA recommends secondary standards to water systems but does not require systems to comply, however states may choose to adopt them as enforceable standards. In a temperate climate, the recommended level to help reduce tooth decay is one milligram of flouride to every liter of water (1 mg/L), while the minimum recommended value is 0.5mg/L(WHO,2004).The WHO maximum guideline value of 1.5 mg/L is higher than the recommended value from artificial fluoridation of water supplies, which is usually 0.5-1.0mg/L(WHO,2004).

These values vary according to local conditions including climate and altitude. In hotter climates where water consumption is much more frequent, the dosage of flouride within the drinking water needs to be modified based on average daily intake. The majority of flouride is consumed through drinking water and food with lesser consumption contributed from toothpaste (IPCS, 1984).Thus diet and exercise also play a large role on the quantity of bodily fluoride intake within a day. There has also been a direct correlation that shows that high altitudes can increase fluoride retention within the body and thus can have an effect on dental and skeletal appearance and structure, independent of fluoride intake and exposure (IPCS, 2002)

2.6.1 Drinking water from around the world

Fluoride content in drinking water varies around the world depending on the geographical location. Many factors affect the fluoride content such as volcanic rocks, granite and gneissic rocks and sediments of marine origin in mountainous areas. These rocks, high in fluoride content, are often found underground affecting groundwater. Thus high concentration of fluoride in water are generally found in groundwater (WHO, 2004).Dangerous levels of fluoride that are increasingly found in groundwater in South and South-eastern Asia are of growing concern, along with infectious or other toxic substances (WHO, 2004).An example from around the world with volcanic activity leading to high fluoride concentration in the waters in Tanzania and the area surrounding the East Africa Rift system. Many of the lakes in this area have high fluoride concentration reaching up to 1640mg/L and 2800mg/L (IPCS,2002).

2.7 Effects of Fluoride on Humans

Like many other nutrients and substances, fluoride is beneficial in small amounts but toxic in large amounts. Fluoride is beneficial to health if the concentration of the fluoride ion (F-) in drinking water is less than 1.5mg/L (WHO,1994). A higher concentration causes serious health hazards. The disease caused manifests itself in three forms namely; dental, skeletal and non-skeletal fluorosis. A small number of case reports have documented toxic levels of intake of fluoride (Burt and Eklund, 1999).

2.7.1 Dental Fluorosis

Dental fluorosis refers to a set of defects of enamel associated with hypoplasia or hypomineralization of dental enamel and dentine as a result of excessive ingestion of fluoride during the critical period of tooth formation. Small amounts in ingested water are usually considered good to have a beneficial effect on the rate of occurrence of dental caries, particularly among children. On the other hand due to its strong electronegativity, fluoride is attracted by positively charged calcium ions in teeth and bones. Excessive intake results in pathological changes in teeth and bones, such as mottling of teeth or dental fluorosis followed by skeletal fluorosis (Saralakumari and Ramakrishna, 1993).

Dental fluorosis ranges from barely perceptible striations in the enamel to severe pitting and subsequent staining. Consequently, its cosmetic significance depends upon its severity. Fluorosis is, however, only one cause of a wide range of defects of tooth enamel. A number of indexes have been developed to describe the extent and severity of fluorosis. Recent reviews have suggested that the prevalence and severity of dental fluorosis has increased in both fluoridated and non-fluoridated communities with the latter exhibiting the largest increase of all (Lewis and Banting, 1994; Clark, 1994). A review by Clark (1994) of North American studies published prior to 1994 indicated that prevalence ranged from 35 to 60% in fluoridated communities and from 20 to 45% in nonfluoridated communities. These increases have been attributed to the consumption of fluoride from sources other than community water supplies (Lewis and Banting, 1994).

Although they are largely confined to the so called 'very mild' and 'mild' categories of dental fluorosis the increases are a cause for concern. The rationale underlying this concern is that fluorosis at this level is discernable by children aged 10 years and over and can lead to embarrassment, self-consciousness and a decrease in satisfaction with the appearance of the teeth (Spencer *et al.*, 1996). This work confirms and expands previous surveys which have shown that lay people can detect fluorosis and both professionals and lay people view the more severe forms as having negative consequences for children (Riordan, 1993; Clark, 1994; Hawley *et al.*, 1996). If the descriptions of the 'very mild' and 'mild' categories of Dean's Fluorosis Index are reviewed, it is by no means certain that they are insignificant to the individuals affected. These terms were coined in the 1930s when concerns with and awareness of appearance were less marked than at the present time. Consequently, these professionally-based judgments may need to be modified in the light of contemporary patient concerns. Certainly, the assumption that 'very mild' and 'mild' forms of fluorosis are acceptable, which underlies much current thinking about fluoridation, may need to be reconsidered. The studies on prevalence are grouped according to which of three indexes were used to measure fluorosis; the Community Fluorosis Index, the Tooth Surface Index of Fluorosis and the Thylstrup and Fejerskov Index.

North American studies, which confined their estimates to children who were life-long residents of fluoridated and non-fluoridated communities respectively, reported prevalence rates of 20 to 75% for the former and 12 to 45% for the latter. European studies reported ranges of 54 to 79% and 14 to 36%, respectively. Studies from Mexico and Brazil reported rates of 61 to 64% and 31 to 50%, respectively.

Two U.S. studies using repeated cross-sectional designs were undertaken by the same investigators and provide the best recent estimates of trends in fluorosis. In the fluoridated city the proportion of children who had a TSIF score of 1 or more increased from 45% in 1992 to 65% in 1994 (NS). In the non fluoridated city there was a significant increase from 18 to 33%. Kumar and Swango (1999) also compared 7 to 14 year old children who were life-long residents of a fluoridated community, Newburgh, and a non-fluoridated community, Kingston. Dean's CFI indicated a significant increase in both communities between 1986 and 1995; from 7.9 to 18.6% in the former and from 7.4 to 11.7% in the latter. The difference in rates between the studies is probably due to the fact that Dean's CFI has a "questionable" category which is categorized as 'normal' for the purpose of calculating prevalence estimates. While water fluoridation, infant formula, fluoride supplements and fluoridated toothpastes are risk factors for dental fluorosis, efforts to reduce children's exposure to fluorides during the years of enamel formation have focused on discretionary sources. Reducing fluoride levels in infant formulas, changing practices of preparing formula to avoid the use of fluoridated water, reducing the use of fluoride supplements, ensuring the availability of low fluoride toothpastes and increasing compliance with appropriate tooth brushing practices in early childhood have been recommended by a number of authorities (Spencer *et al.*, 1996). Since these involve altering the practices and behaviours of commercial organizations and individuals, their likelihood of success is at best questionable. It has often been claimed that one of the advantages of community water fluoridation, and a major factor in terms of its effectiveness, is that it does not rely on organizational or individual compliance with health recommendations.

Clearly, the simplest way of reducing the prevalence of fluorosis in child populations is to cease to fluoridate community water supplies. Whether or not this is an acceptable option depends on the balance of benefits and risks with respect to dental caries and fluorosis. This balance is difficult to assess when the discussion takes place at the level of disease. The ultimate concern here should be to maximize quality of life outcomes.

However, data on the effects on health and well-being of the relatively small decreases in caries rates in children and adolescents currently achieved by water fluoridation is nonexistent. Similarly, data on the negative health consequences of current levels of fluorosis in child and adolescent populations is scant

2.7.2 Bone Health

Fluoride affects the skeleton in three ways. Firstly, it incorporates into bone tissue by replacing the hydroxyl group of hydroxylapatite to form fluorapatite (Kleerekoper, 1998). The latter is more resistant to osteoclastic resorption, which may result in an altered bone remodeling cycle. This in turn may lead to bone with impaired biomechanical properties, since remodeling is an integral part of skeletal health. The degree to which fluorapatite is mixed with hydroxylapatite is dependent on fluoride dose and exposure time. It has been found that fluoride absorbs more rapidly in growing bone than after peak bone mass has been achieved. Secondly, in higher serum concentrations, fluoride is anabolic to bone in that it increases cancellous bone mass (Kleerekoper, 1998; Lau, 1998, Kleerekoper, 1994). It appears that the threshold dose is between 11 and 14 mg/day for fluoride to exert its osteoanabolic effect. This effect is linear with time for at least six and possibly ten years or more. Thirdly, in dose-dependent manner fluoride may cause impairment in mineralization of the newly synthesized osteoid and consequently affect biomechanical properties of the bone (Kleerekoper, 1998; Fejerskov, 1996).

2.7.2.1 Skeletal fluorosis

The intake of fluoride at high levels for protracted periods results in a systemic osteosclerosis known as skeletal fluorosis or osteofluorosis. This condition is characterized by a thickened cortical and cancellous bone with signs of hypomineralization and mineralization defects, spur bony formations at tendon insertions and ossification of interosseous membranes and ligaments. These changes are more pronounced in the central skeleton and to a lesser degree in the skull and the peripheral bones (Fejerskov, 1996). Clinically they range from asymptomatic radiographic bone mass increase to crippling skeletal fluorosis involving spine and joint deformities and dysfunctions, muscle wasting and neurological problems due to spinal cord compression (Whitford, 1994; Kleerekoper, 1998). Additional clinical manifestations that may indicate toxic effects of chronic fluoride exposure have been observed in skeletal fluorosis. They include gastrointestinal symptoms, the most common being abdominal pain associated with chronic atrophic gastritis (Dasarathy *et al*.,, 1996), a decreased level of serum testosterone, suggesting the possibility of an adverse effect on spermatogenesis (Susheela, 1996) and An increase in the levels of markers of inflammatory reactions; haptoglobin and C-reactive protein (Susheela, 2007).Most estimates indicate that crippling fluorosis is associated with chronic fluoride exposures of above 10 mg/day for at least ten years. These exposures occur as either endemic (exposure to the naturally fluoridated drinking water) or industrial (e.g. exposure to the cryolite dust) (Fejerskov, 1996; Whitford, 1996). Beside the dose and duration of fluoride exposure, the development of skeletal fluorosis is influenced by various other factors. The most common are age, physical activity, kinetics of bone remodeling, nutritional status and renal insufficiency (Kleerekoper, 1996). Epidemiological studies of bone mineral density have not detected changes consistent with skeletal fluorosis resulting from the consumption of drinking water containing fluoride at the concentrations considered optimal for caries prevention. Skeletal fluorosis causes crippling and severe pain and stiffness of the backbone and joints (Bulusu and Nawlakhe, 1992)

2.7.3 Cancer

Numerous studies have been undertaken to determine if water fluoridation is linked to increases in the risk of cancer. Many studies claiming that such a risk exists have been reanalyzed and found to provide no evidence of a link. Moreover, many used the correlational ecologic design which has significant limitations in terms of establishing cause and effect relationships.

A recently published ecological study (Tohyama, 1996) did find a significant correlation between fluoride concentration in drinking water and uterine cancer mortality in 20 municipalities in Okinawa, Japan. This association remained significant after adjusting for a number of confounders such as population ratio, income gap, stillbirth rate and divorce rate. However, the study did not control for more relevant confounders such as smoking and sexual activity.

A 1990 animal study showing a possible link between fluoride and osteosarcoma stimulated a number of more rigorous studies using case-control designs which were published between 1994 and 1999. Three case-control studies from the U.S. found no association between exposure to fluoridated drinking water and osteosarcoma (Moss *et al.*, 1995; McGuire *et al.*, 1995; Gelberg *et al.*, 1995). For example, a multi-centre study involving 147 patients and 248 controls found no differences between the proportions exposed to optimally fluoridated water or the average yearly exposure (McGuire *et al.*, 1995). The study by Gelberg *et al*., (1995) found no association between fluoride exposure and osteosarcoma in a study of 130 cases aged 24 years or less and 130 age and sex matched controls. The finding of no association held whether fluoride exposure was based on data provided by patients or their parents. The study also suggested that there may be a protective effect for males.

Studies of other cancer sites, one an ecologic study from South Africa (Bourne and Aggett, 1994) and a case-control study of bladder, colon and rectal cancer in Ontario (Marrett and King, 1995) showed no association between water fluoridation and increased risk of cancer. Two recent reviews of the literature also concluded that there is no evidence that fluoride in the water supply is linked with an elevated risk of cancer at anybody site (Cook-Mozaffari, 1996).

2.7.4 Child Development

Early studies of child development in fluoridated and non-fluoridated communities focused on physical health. No differences were documented with respect to body processes, blood chemistry, vision, hearing or any other general health parameter. More recent studies have focused on intellectual development. Two conducted in China claimed to have found differences in IQ between children exposed to differing levels of fluoride.

Although both fell outside the inclusion criteria they were reviewed to illustrate the flaws in this research. The first (Zhao *et al.*, 1996) compared the IQ of children in one village where the water supply contained 4 ppm fluoride and one village where the concentration of fluoride was 0.9 ppm. The mean IQ of random samples of children was 105 in the former and 98 in the latter, a statistically significant difference. In both villages, children of parents with a higher education had a higher IQ. However, analysis of mean IQ scores adjusting for the confounding effect of parental education was not undertaken. Nor was the effect of other potential confounders taken into account. The second study compared the IQ scores of children from four areas with differing levels of dental fluorosis. The source of fluoride was not water but soot due to coal burning. The Dental Fluorosis Index scores varied from 0.4 to 3.0. The latter is seen in areas fluoridated to approximately 8 ppm. Significant differences were observed in the IQ scores of children living in non-fluorosis and severe fluorosis areas (90 vrs 80, respectively). It is not clear if the children examined in each area were randomly sampled. Nor was any attempt made to control for potential confounders or the effects of other pollutants present in soot from coal.

Besides dental and skeletal fluorosis, excessive fluoride (F) intake can also affect the central nervous system without first causing the physical deformities associated with skeletal fluorosis. Thus, as an extreme example, toxic neuronal injury in the form of tetaniform convulsions in a 12-year-old boy from ingestion of 1-ppm fluoridated drinking water was described in detail and found to subside with non fluoridated water (Waldbott *et al*., 1957) Over the last two decades more subtle injury from flouride in the form of lower intelligence has been reported in China (Chen, 2008) India (Susheela *et al.,* 2007) and Iran (Seraj *et al*., 2006)

Thus, Liu *et al*., 1995 in comparing the lower IQ scores of 60 children age 10–12 in a high F water (3.15mg/L) area with those of 58 control children of the same age in a nearby low F water (0.37 mg/L) area found “there were significantly more borderline and low IQs in the high F area (13/60) than in the low F area (2/58) ($p<0.01$). Similarly, in an earlier larger study, Chen *et al.*, 2008 observed a significantly lower average IQ of 320 children age 7–14 in an area with 4.55 mg F/L in the drinking water compared to the IQ of 320 children of the same age born and residing in an area with 0.89 mg F/L in the drinking water ($p<0.01$) (Chen et al.,2008).In another early investigation, Guo et al.,1991 compared the IQs of 7–13 year-old children living in areas with and without endemic dental fluorosis and found a significantly lower IQ in the 7–9 year-old children in the endemic fluorosis area.

Kidneys are among the most sensitive body organs in their histopathological and functional responses to excessive amounts of flouride (Hodge and Smith, 1965).They are the primary organs concerned with excretion and retention of flouride and thus are generally involved in chronic intoxication. In humans, only a few reports pertaining to kidney involvement in endemic fluorosis are available (Shortt *et al.*, 1937). Flouride toxicity is the more abundant threat to the common people who are living in the flouride content areas in the globe. Flouride toxicity will affect all the parts of the human system leading to altered life span (Schiffl and Binswanger, 1980).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of study area.

Sumbrungu is located in the western part of the Upper East region, eight kilometers from Bolgatanga. Bolgatanga is the capital of Upper East Region in the northern part of Ghana (Fig. 1). Its geographical coordinates are 10° 47' 8" North, 0° 51' 5" West and 180 meters altitude above the sea level.

Temperatures in Bolgatanga range from 18.9°C to 38.85°C with a mean temperature of 31°C (87°F). Rainfall in Sumbrungu varies from 0.0 to 672.0 (mm/month). The mean Annual Rainfall is between 950mm – 1100 mm. There is an alternating wet and dry seasons in Sumbrungu. The rainy season is from May to October and the dry Season from October to March with harmattan winds in November and December. They experience a maximum temperature of 45°C in March/April and a minimum temperature of 12.8ºC in August. The relative rainfall variability is 17% in the wet season and the rainfall is very erratic. Humidity in Sumbrungu is 91% from July to September, and 15% from December to March.

Geology is dominated by ancient crystalline rocks, incorporating mainly metamorphosed sediments and granite. Minor occurrences of more recent unconsolidated sands, clays, quartz which are associated with fluoride (BGS, 2008). The Upper Regions of Ghana are underlain mainly by Precambrian granite rocks composed largely of granites, granodiorites and gneiss. Other metamorphic rocks such as schists and phyllites may also occur. For the Upper East region, and also the rocks are mainly Granites and some

Birimian rocks which is known to have high concentration of fluoride (Smedley *et al*., 1995).

The topography of the region varies from gently undulating to distinctly hilly and mountainous. Flat characterized by gentle slopes ranging from 1% to 5% with inselberg outcropped uplands with more than 10% slope. Guinea Savannah Woodland consisting of short deciduous trees widely spaced and a ground flora composed of different species of trees and shrubs. Bushfires are a persistent feature of environmental degradation and deforestation.

Most inhabitants within this community do not have access to good treated water hence; they depend on water from wells and boreholes for their daily needs.

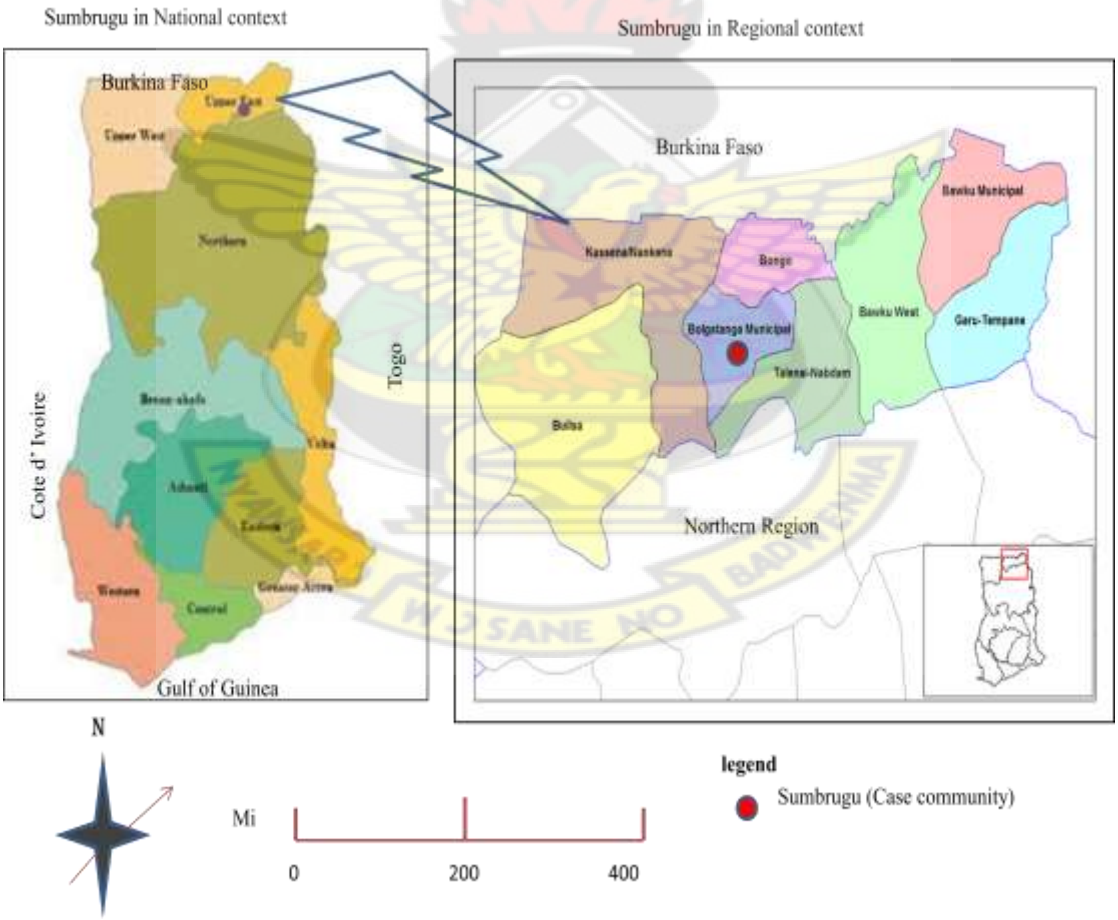

Figure 3.1: Map of Ghana showing location of Sumbrungu in the Upper East Region.

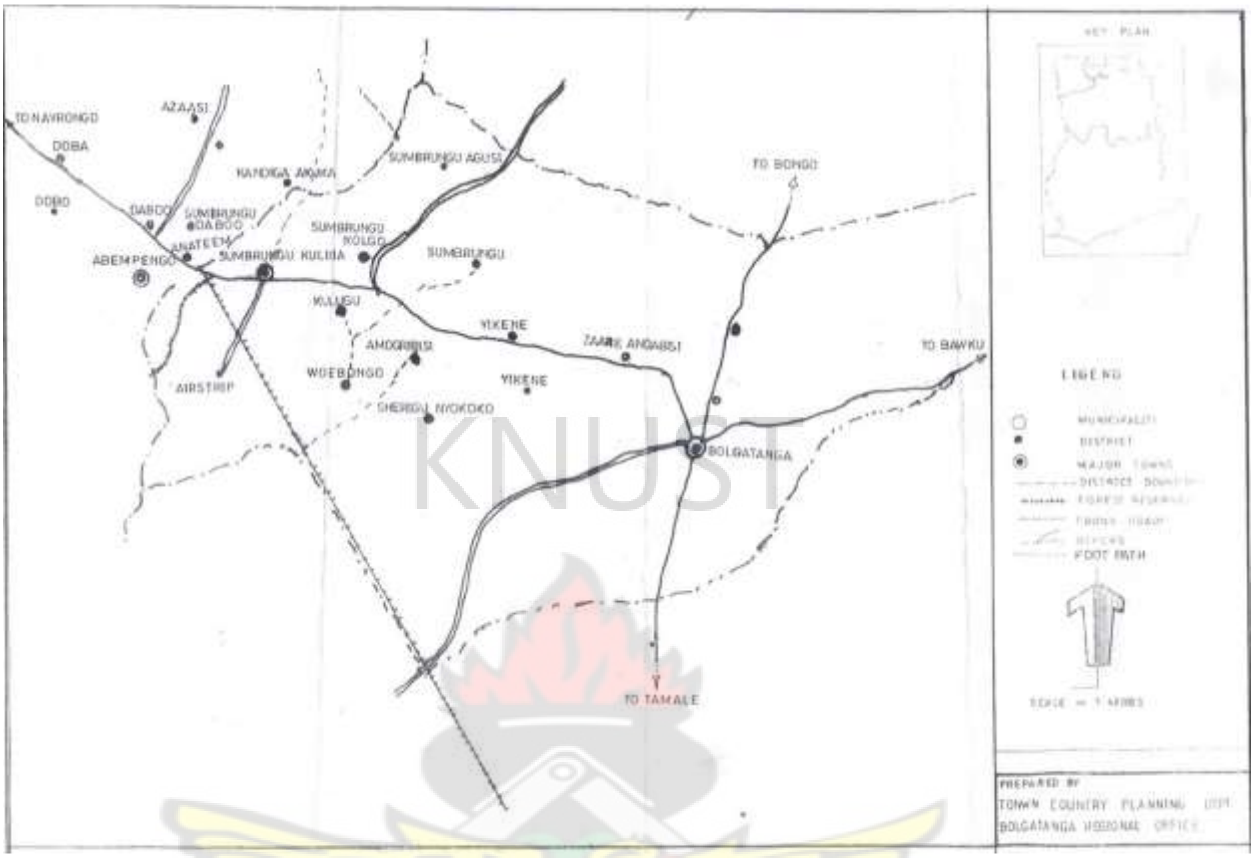

Figure 3.2: A map of Sumbrungu showing sampling sites.

3.2 Sampling Sites and Collection.

Water samples were taken from boreholes, wells and surface water. A total of 162 samples from 27 water sources made up of 15 wells, 11 boreholes and surface water were sampled from Sumbrungu (Fig 3.2). The surface water sample was taken from River Atankiri which is located at the western part of Sumbrungu. During water sampling, samples were collected in triplicate at each sampling point and stored in 500ml polyethylene bottles which were previously washed with deionised water (APHA, 1998).

The boreholes were pumped several times to stabilize the electrical conductivity and the plastic bottles washed three times with the sample before filling up with water samples. Water samples from wells were collected by drawing using a plastic container. The cap was securely fixed, labeled and kept in an ice box during transportation and later refrigerated in the laboratory prior to analysis within 24 hours.

Water samples were collected at two different times. Samples were collected in January 2012 to February, 2012.

Plate 3.1: Sampling of water from a borehole at Sumbrungu.

3.3 Fluoride determination

3.3.1 Test Procedure

A round test tube was filled with water sample to the 10ml mark and one fluoride No.1 tablet was then crushed and mixed to dissolve. Another one fluoride No.2 tablet was crushed and mixed to dissolve. The content was allowed to stand for 5 minutes to allow full colour development. The photometer reading was then done to obtain fluoride concentration in mg/L.

3.4 Epidemiologic design

According to the Bucodental Health Survey, (WHO, 1994) students between 12 and 15 years old were selected because at this age all permanent teeth (except third molars) have erupted, and dental fluorosis is evident. In addition to this, they are able to answer a structured questionnaire.

The criteria of inclusion for the pupils were:

1. Both sexes.
2. Between 12 to 15 years old.
3. Were born and live in the community being sampled.
4. Active students and voluntary participation in the study.
5. Have not undergone orthodontic treatment.

For this study, ethical aspects were considered that guaranteed the dignity and the well-being of the subjects involved, ensuring respect, confidentiality and the protection of human rights. An interview with the health and school authorities of Sumbrungu was undertaken in order to obtain a letter of approval for the community.

3.5 Assessing prevalence of dental fluorosis using Dean's index

The prevalence of fluorosis was determined using the Dean’s fluorosis index. A total sample of 120 Children between the ages of 12 and 15 were examined for dental fluorosis using the Dean’s Fluorosis index. For each student, dental brushing was undertaken, and the teeth were dried with sterile gauze.

Then all the permanent superior teeth were evaluated by visual inspection in natural morning light, using a sterile dental mirror and explorer, and other material necessary to guarantee the bio-security measures. The registry of dental fluorosis was based on the two most affected teeth.

The dental fluorosis diagnosis was carried out according to the following criteria:

Unaffected: The enamel is translucent. The surface of the tooth is smooth, glossy, and usually has a pale creamy white color.

Questionable: The enamel shows slight changes ranging from a few white flecks to occasional white spots. This classification is utilized in those instances in which a definitive determination of the mildest form of fluorosis is not warranted and a classification of unaffected is not justified.

Very mild: Small opaque paper-white areas are scattered over the tooth surface, but do not involve as much as 25% of the surface.

Mild: White opaque areas on the surface are more extensive, but do not involve as much as 50% of the surface.

Moderate: White opaque areas affect more than 50% of the enamel surface.

Severe: All enamel surfaces are affected. The major aspect of this classification is the presence of discrete or confluent pitting.

$$\text{Prevalence} = \frac{\text{the proportion of the population with very mild or higher levels of dental fluorosis}}{\text{Total population}} \times 100$$

Plate 3.2: A 14 year old girl suffering from a mild form of dental fluorosis

Plate 3.3: A 15 year old boy suffering from a moderate form of dental fluorosis

Plate 3.4: A 13 year old boy suffering from a very mild form of dental fluorosis

Plate 3.5: A 12 year old girl suffering from a moderate form of dental fluorosis.

Plate 3.6: A 15 year old girl suffering from a moderate form of dental fluorosis

Plate 3.7: A 15 year old boy showing a normal form of dental fluorosis.

3.6 Community fluorosis index (CFI)

In order to establish the Community fluorosis index(CFI), statistic consideration (p) has the following values: Criteria of Normal has score 0 and $p = 0$, Questionable score 1 and $p = 0.5$, Very mild score 2 and $p = 1$, Mild score 3 and $p = 2$, Moderate score 4 $p=3$ and Severe score 5 and $p = 4$.

CFI was estimated with the summa of the number of affected students multiplied by the degree of affection (statistics consideration) and divided between the total numbers of examined pupils:

$$\text{CFI} = \frac{\Sigma\ (\text{Number of students with fluorosis} \times \text{consideration})}{\text{Total number of students examined}}$$

Interpretation of the CFI: Dean indicates that if the CFI is above 0.6, it results to a public health problem and it justifies an increased attention to the population (Dean, 1942).

3.7 Statistical Analysis

A one way analysis of variance (ANOVA) was performed on the data using SPSS version 17, at a significance level of 5%. The Least Significant Difference (LSD) test was used to locate differences in mean concentration of fluoride. Standard error of the means and coefficient of variation were also computed.

3.7.1 To compare concentration from different water sources.

Student *F*- test, with $p < 0.05$, 95% CI, (Microsoft Excel, 2007)

3.7.2 To estimate prevalence of dental fluorosis

Mean; Chi^2 with 95% CI, $p < 0.05$ (Microsoft Excel, 2007).

CHAPTER FOUR

4.0 RESULTS

4.1 Distribution of fluoride in the different water sources in the Sumbrungu.

Fluoride concentration in well water samples ranged from 0.65-1.06 (Table 1). Out of the fifteen wells sampled, ten were not significantly different ($p<0.05$) in fluoride concentration but were significantly ($p=0.0002$) different in the five other wells sampled. Of these wells, 47 % had their fluoride levels higher than 1.0 mg/l but none (0%) of the well samples had a fluoride concentration greater than 1.5 mg/L (Table 1).

Table 4.1: Distribution of fluoride in the different well water sources in Sumbrungu.

Sampling Sites	Fluoride concentration (mg/L)	
	Mean	**Range**
ANA	$1.10^{a}\pm0.10$	1.00–1.20
KUL	$0.90^{b}\pm0.05$	0.85–0.95
KK	$0.75^{b}\pm0.09$	0.65–0.80
AGU	$1.05^{a}\pm0.05$	1.00–1.10
AG	$1.10^{a}\pm0.05$	1.05–1.15
ABI	$1.08^{a}\pm0.03$	1.05–1.10
KN	$0.95^{a}\pm0.13$	0.85–1.10
AD	$0.91^{b}\pm0.16$	0.80–1.10
AWB	$0.88^{b}\pm0.03$	0.85–0.90
AGUI	$1.12^{a}\pm0.13$	1.00–1.25
AGUI	$1.10^{a}\pm0.15$	0.95–1.25

AUU	0.97[a]±0.10	0.85–1.05
AUN	0.83[b]±0.03	0.80–0.85
ADU	1.02[a]±0.13	0.90–1.15
KB	1.07[a]±0.03	1.05–1.10

Numbers in rows followed by different superscript are significantly different at $p< 0.05$

The mean concentration of fluoride in the surface water sources in Sumbrungu ranged from 0.30–0.45(Table 2).This was considerably lower than the levels indicated by the WHO (2004) guidelines for fluoride concentration of 1.50mg/L.

Table 4.2: Distribution of fluoride in the surface water sources at Sumbrungu.

Sampling site	**Fluoride Concentration (mg/L)**	
	Mean	**Range**
RA	0.37±0.08	0.30–0.45

Boreholes water fluoride concentration ranged from 0.65-1.25 (Table 3).Ten out of the eleven boreholes sampled were not significantly ($p<0.05$) different but one was significantly ($p=0.0001$) different.

Out of the eleven boreholes, 70% had fluoride levels greater than 1 mg/L but none (0%) of the samples had a fluoride concentration above 1.5 mg/L (Table 3).

Table 4.3: Distribution of fluoride in the different borehole water sources at Sumbrungu.

Sampling Sites	Fluoride concentration (mg/L)	
	Mean	Range
AW	$0.73^{b}\pm0.10$	0.65–0.85
AB	$1.15^{a}\pm0.09$	1.10–1.25
AI	$0.95^{a}\pm0.13$	0.85–1.10
KG	$1.05^{a}\pm0.09$	0.95–1.10
AA	$0.97^{a}\pm0.13$	0.85–1.10
AAA	$1.10^{a}\pm0.10$	1.00–1.10
KA	$1.22^{a}\pm0.10$	1.10–1.30
DAB	$1.15^{a}\pm0.09$	1.10–1.25
DABO	$1.10^{a}\pm0.05$	1.05–1.15
BO	$1.22^{a}\pm0.03$	1.20–1.25
ANG	$1.05^{a}\pm0.05$	1.00–1.10

Numbers in rows followed by different superscript are significantly different at $p< 0.05$

Fluoride concentration in 81 water samples from the different sources ranged from 0.3-1.30 with a mean of 0.99±0.19 mg/L (Fig. 1 and Table 4).The borehole water samples contained the highest amount of fluoride. The mean concentration in 33 borehole water samples was 1.06±0.14 with a range of 0.65–1.30 mg/L. The fluoride concentration in 45 well water samples was in the range of 0.80–1.25 mg/L with a mean of 0.99±0.11.

Surface water contained the lowest amount of fluoride with a mean of 0.37±0.08 for the samples studied. The concentration of fluoride in these surface waters ranged from 0.30–0.45 mg/L (Fig. 1 and Table 4)

The unpaired F-test demonstrated that the concentration of fluoride in all the different water sources; boreholes, wells and the river at Sumbrungu were not significantly different at ($P<0.05$).

Table 4.4: Distribution of fluoride in the different water sources at Sumbrungu.

Water Sources	Number of Samples	Fluoride concentration(mg/L)	
		Mean	Range
Boreholes	33	1.06±0.14	0.65–1.30
Wells	45	0.99±0.11	0.80–1.25
Surface Water	3	0.37±0.08	0.30–0.45

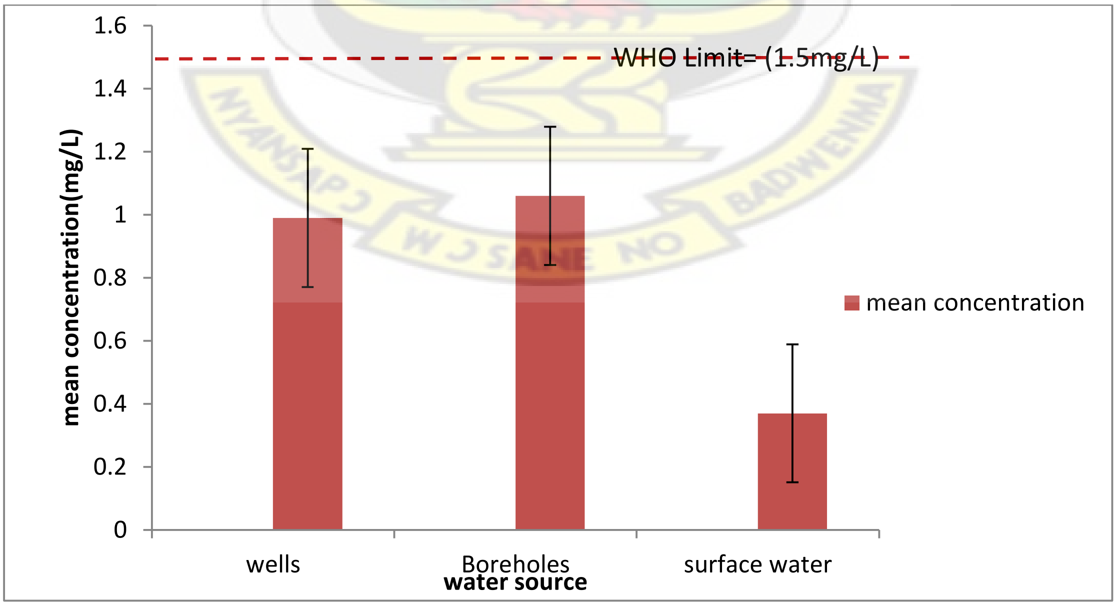

Figure.4.1: The fluoride concentration in the different water sources.

4.2 Determination of Prevalence and Community fluorosis Index at Sumbrungu.

Table 5 depicts the prevalence of dental fluorosis. The overall dental fluorosis in the sample population was 65%, where 28% were very mild, 21% mild, 14% moderate and 2% severe. In the 120 students from 12 -15 years old sampled all the grades of fluorosis were present.

Table 4.5: Dean's Index to determine prevalence of dental fluorosis at Sumbrungu.

Dean's Index	N	%	Total sample size	Prevalence (%)
Very mild	34	28	120	**65**
Mild	25	21		
Moderate	17	14		
Severe	2	2		
Total	78	65		

A community fluorosis Index of 1.30 was determined for Sumbrungu (Table 6). According to Dean (1942) values, if the CFI is above 0.6 it is considered a public health problem. The results obtained in this work indicate that for the Sumbrungu community, it is very possible that there is a public health problem.

The dental fluorosis results had associations with sex and age. All the scores of dental fluorosis for males and females in the bivariate analysis showed that there was no significant correlation between dental fluorosis and sex $p = 0.27$; similarly, all the degrees of dental fluorosis were stratified in the rank of 12 - 15 years old and there was statistically significant difference regarding age $p = 0.01$.

Table 4.6: Dean's Index to determine the Community Fluorosis Index (CFI) of Sumbrungu.

Dean's Index	N	Score	Σ Score
Unaffected	18	0	0
Questionable	24	0.5	12
Very Mild	34	1	34
Mild	25	2	50
Moderate	17	3	51
Severe	2	4	8
Total	**120**		**155**

Community Fluorosis Index (CFI) = 1.3

Table 7 depicts the prevalence of dental fluorosis according to gender and age. Gender distribution in the sample was 66 (55%) boys and 54 (45%) girls. Overall, 65% of the sample showed some grades of dental fluorosis. The prevalence for male and female was 71.2% and 57.4% respectively. Dental fluorosis was found to be more prevalent among males than females. However, gender difference was not statistically significant (P= 0.27).The different ages from 12-15 recorded different prevalence. The minimum prevalence for the ages was 60.0% for 12 years whiles the maximum was 69.4% at 15 years. The prevalence of dental fluorosis was found to increase with age.

Table 4.7: Prevalence of dental fluorosis according to gender and age.

Variables	Number of Children		Prevalence (%)
	Examined	Affected	
Gender			
Male	66	47	71.2
Female	54	31	57.4
Age Group			
12	30	18	60.0
13	22	14	63.6
14	32	21	65.6
15	36	25	69.4

CHAPTER FIVE

5.0 DISCUSSION

The study shows that mean fluoride concentration in all the water sources sampled in Sumbrungu was 0.99±0.19 mg/L (Fig. 1 and Table 4). Concentrations were highest in borehole water with a mean fluoride concentration of 1.06±0.14, followed by well water, 0.99±0.11, and the lowest was in surface waters, 0.37±0.08 (Table 1, 2 and 3). However, none of these water sources (wells, boreholes and surface waters) had fluoride concentrations higher than the 1.5 mg/L guideline value set by the WHO (2004). The unpaired F-test demonstrated that the concentration of fluoride in all the different water sources; boreholes, wells and the river at Sumbrungu were also not significantly ($P<0.05$) different.

This measured fluoride in the different water sources could have originated from fluoride bearing minerals in the area. Apambire *et al*., (1997) have suggested that the main sources of groundwater fluoride in granitic rocks are the dissolution and anion exchange with micaceous minerals and their clay products. There were no clear trends in the concentration of fluoride in the groundwater samples (wells and boreholes) which tend to suggest that most of the water samples studied had different fluoride concentrations. This uneven distribution of fluoride in groundwater samples can be attributed to uneven distribution of fluoride containing minerals in the rocks. However, the concentration of fluoride in the boreholes was higher than that in the wells. This was also observed in a similar study by the British Geological Society Survey (2008) which noted marked variations in the fluoride concentrations with depth in the groundwater from Bongo in the Bolgatanga district. The shallow groundwater from hand dug wells had significantly lower concentrations than tube well (boreholes). This is as a result of dilution by recent recharge (BGS, 2008) and the fact that the boreholes are deeper than the hand-dug wells.

Therefore the water in the boreholes encountered more fluoride containing minerals hence its higher concentration.

The generally low fluoride content in the surface water studied is not an isolated case as earlier work by Antwi, (1995) suggests that freshwater systems in Ghana have lower concentration of flouride compared to boreholes. Natural fluoride in water is derived from the solvent action of water on the rocks and soils of the earth's crust. Fluoride concentration of natural waters therefore depends, among other things, on the solubility of fluoride-containing mineral in the underground water and the porosity of the rocks and soil through which the water passes (Smith, 1983). Geologically, the Upper Regions of Ghana are underlain mainly by Precambrian granite rocks composed largely of granites, granodiorites and gneiss. Other metamorphic rocks such as schists and phyllites may also occur.

The gender of the students used for the study at Sumbrungu showed no significant differences using the criteria of the Dean´s Index. From the epidemiological point of view, females and males have the same probability of suffering dental fluorosis (Vazquez-Alvarado *et al*., 2010).In this study; females were found to have less fluorosis than males. This is consistent with other studies conducted among rural school children in Haryana (Singh *et al*., 2001), Karnataka (Chandrashekar and Anuradha, 2004) and rural Tanzania (Mabelya *et al*., 1997). This was due to physical factors where females tried to remove the unsightly stains through manual abrasion with sand or ash and not due to internal genetic differences. However, in Kerala a higher prevalence among girls was reported (Gopalakrishna *et al*., 1999).

In the present study, nearly two-thirds (65%) of children had experienced dental fluorosis. However, severe fluorosis was only 2%, with 28% being very mild, 21% mild and 14% moderate. This is similar to the 69.35% in rural school children in Lucknow district, India (Nanda, 1972). However, a higher prevalence of 92.73% was recorded among school children of similar age group in the village of Juai Kalan, Bhiwani district, Haryana, India (Dahiya *et al.*, 2000) and in the Mexican cities of San Luis Potosi (Grimaldo *et al*., 1995), Jalisco (Hurtado and Gardea-Torresdey,2005) and Queretaro (Sánchez *et al*., 2004) in Mexico, where the water for human consumption is known to contain fluoride because of the geology of the areas, show a prevalence of dental fluorosis of 98, 98 and 89.5%, respectively. Also, a lower prevalence of 16.8% has been reported amongst rural school children in Kerala (Gopalakrishnan *et al*., 1999).

In this study, the prevalence of dental fluorosis was found to increase with age. This trend is consistent with the findings of the Dental Council of India (2004) among children in rural Tamil Nadu. Similar findings have been documented among rural school children in Haryana (Dahiya, *et al*.,2000).Possible reasons for the lower prevalence in the younger age groups may be that; the period of enamel formation for primary teeth is shorter and hence the exposure to fluoride is shorter. The enamel of primary teeth is thinner than that of permanent teeth (Thylstrup,1978) and the rapidly growing skeleton of children may absorb fluoride at more rapid rate since fluoride is a hard-tissue seeker and is thus less available for primary teeth (Thaper,1989). On the other hand, the greater body size and weight, the increased physical activity and the kind of food consumed may lead to a higher water intake and thus a higher prevalence in older age groups (Nanda, 1972).

The regions of Ghana most vulnerable to high fluoride concentrations and associated dental fluorosis are the arid zones of the north and areas where bedrock geology is dominated by granite. The Upper Regions of Ghana are therefore considered to be the most likely areas to experience potential problems. Concentrations of fluoride in excess of 1.5 mg/l (up to 3.8 mg/l) have been observed in Bolgatanga and Sekoti in the Upper East Region in close association with granitic rock types (Smedley *et al*., 1995). Occurrence of dental fluorosis is common in these areas. Moreover, in the area, there are deposits of limestone, kaolin, clay, quartz and silicium, which are associated with fluoride in water (Geological Monograph, 1992; Gaciri and Davies, 1993).

In the present study, the Sumbrungu Community Fluorosis Index was 1.30. According to Dean (1942) values, if the CFI is above 0.6 it is considered a public health problem hence the Sumbrungu community has a problem. Although the mean fluoride concentration was lower than the guideline value given by the World Health Organization (WHO), the Community Fluorosis Index was 1.30.At a lower mean concentration than the 1.5mg/L, a lower CFI should be recorded. However, if the mean concentration is low and the CFI values indicate fluorosis as a public health problem, then there should be another probable cause of fluorosis. Looking at the spatial variation of fluorosis and fluoride content of water in an endemic area (5 villages in the North West Province) Zietsman (1991) found a surprisingly high fluorosis prevalence of 33.5% in association with absolutely and relatively low fluoride concentrations of 0.54 mg/L and even 0.4 mg/L. Van der Merwe *et al.,* (1977) also observed a higher fluorosis prevalence (11.4%) than generally would be expected at Mabeskraal a low fluoride area (0.02-0.2 mg/L).

On the other hand Pontigo-Loyola *et al*., (2008) reported an overall prevalence of dental fluorosis of 83.8% and a Community Fluorosis Index of 1.85 in three communities in Tula de Allende, Mexico. Also in another study by Vazquez-Alvarado *et al*., (2010) the concentrations of fluoride in drinking water had a mean of 1.41 mg/L with a fluorosis prevalence of 85% and a Community Fluorosis Index of 1.6.In the same study the mean value for drinking water in another area was 0.62 mg/L with a prevalence of 4% and Community Fluorosis Index of 0.2.

Background document for development of WHO Guidelines for Drinking-water Quality (2004) states that "In setting national standards or local guidelines for fluoride or in evaluating the possible health consequences of exposure to fluoride, it is essential to consider the intake of water by the population of interest".

The 1.5 mg/L guideline value of WHO is not a "fixed" value but is intended to be adapted to take account of local conditions (WHO,2006).It is particularly important to consider climatic conditions, volume of water intake and other factors when setting national standards for fluoride (WHO, 1994). This point is extremely important, not only when setting national standards for fluoride, but also when taking data from one part of the world and applying them in regions where local conditions are significantly different (WHO, 2006).

In warmer areas, because of the greater amounts of water consumed, dental fluorosis can occur at lower concentrations in the drinking-water (IPCS, 1984; US EPA, 1985a; Cao *et al.*, 1992).

The mean temperature for Sumbrungu in the Bolgatanga metropolis is 31°C (87.5°F). According to the Center for Disease Control (1991) considering the mean air temperature of 21.4°C (38.52°F) the level of fluoride should be under 0.8 mg/L. In countries like Lebanon, there are two different standards; at a temperature of 8-12°C the standard is 1.5mg/L and 0.7mg/L for a temperature of 25-30°C(Lebanon,1996).

From the present study, a mean fluoride concentration of 0.99mg/L for wells and 1.22 mg/L was recorded which resulted in a CFI of 1.33.The low fluoride concentration and a high CFI recorded could be as a result of climatic factors.

In growing children fluid intake may be slightly greater than water loss since some additional water is needed to build new tissues, but generally water intake and water loss will be equal over a 24-hour period.

Excessive temperatures result in a bodily demand for fluid over and above that usually required for normal physiological processes. The extremely high temperature occurring at Sumbrungu in the Bolgatanga metropolis is undoubtedly a major factor contributing to the increased severity of endemic fluorosis observed in Sumbrungu children through its influence on water consumption.

Body weight, physical activity, direct radiation, and humidity may all play a part in the amount of fluid lost by the body and therefore in the amount of fluid ingested to maintain water balance. It has been demonstrated that there is an increase in the sweating rate of about 20 grams per hour for each degree of increase in air temperature (Adolph,1947).As the body losses water through sweating, the body increases the rate of water intake**.** The part of Ghana under consideration has a greater percentage of sunshine than many places. Therefore in Sumbrungu, there is an extremely high radiant heat gain. This climatic factor may indirectly account for the presence of fluorosis.

The higher than expected prevalence of fluorosis at Saulspoort was ascribed to the effect that higher mean maximum daily temperatures have on water consumption and subsequent incidence of fluorosis (Bischoff *et al*., 1976).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The study has shown that fluoride concentration in the different water sources (wells, rivers and boreholes) were lower than the WHO guideline value for fluoride in drinking water. Fluoride concentration in the river water sources were the lowest followed by well water and that in the borehole water was the highest in fluoride. The prevalence of dental fluorosis in the Sumbrungu community was 65% with a Community Fluorosis Index of 1.3; which makes dental fluorosis a public health problem although severe dental fluorosis is only 2%.

6.2 Recommendation

Based on the outcome of the study the following is recommended;

1. Dental Fluorosis definitely appears to be a public health problem in Sumbrungu which require the attention of authorities at the various levels of government. This attention will need to consider defluoridation of water especially since there are no alternative water sources available. It is recommended that defluoridation demonstration programmes establishing the efficacy, effectiveness and feasibility of defluoridation. Where treatment to remove fluoride is practised, it is recommended that chemicals used should be of a grade suitable for use in drinking-water supply as outlined in the WHO Guidelines for Drinking-water Quality.
2. It is also recommended that the standard set by the Ghana Environmental Protection Agency should be revised especially for the Northern regions of the country.

3. The present study acts as a pointer to public health physicians, dentists, chemists, planners, administrators, engineers and water supply authorities. The information furnished can be utilized as preliminary data; it is recommended that a well-designed epidemiological investigation can be undertaken at Sumbrungu and district level to confirm and assess dental fluorosis and to evaluate the risk factors associated with the condition in the study region.
4. Furthermore, it is recommended that a comprehensive study should be carried out and a database of fluoride content in groundwater be created in Bolgatanga.

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APPENDICE

APPENDIX A: STATISTICAL ANALYSIS

Anova tables for boreholes.

BOREHOLES

ONEWAY fluoride BY site /MISSING ANALYSIS /POSTHOC=LSD ALPHA(0.05).

Oneway

Notes

Output Created		18-Sep-2012 10:09:27
Comments		
Input	Data	C:\Users\Queenly\Documents\borehols.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	45
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on cases with no missing data for any variable in the analysis.
Syntax		ONEWAY fluoride BY site /MISSING ANALYSIS /POSTHOC=LSD ALPHA(0.05).
Resources	Processor Time	0:00:00.078
	Elapsed Time	0:00:00.079

[DataSet1] C:\Users\Queenly\Documents\borehols.sav

ANOVA

Fluoride

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.541	14	.039	4.242	.000
Within Groups	.273	30	.009		
Total	.814	44			

Post Hoc Tests

Multiple Comparisons

fluoride

LSD

(I) site	(J) site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.20000*	.07794	.016	.0408	.3592
	3.00	.35000*	.07794	.000	.1908	.5092
	4.00	.05000	.07794	.526	-.1092	.2092
	5.00	.00000	.07794	1.000	-.1592	.1592
	6.00	.01667	.07794	.832	-.1425	.1758
	7.00	.15000	.07794	.064	-.0092	.3092
	8.00	.18333*	.07794	.025	.0242	.3425
	9.00	.21667*	.07794	.009	.0575	.3758
	10.00	-.01667	.07794	.832	-.1758	.1425
	11.00	.00000	.07794	1.000	-.1592	.1592

	12.00	.13333	.07794	.097	-.0258	.2925
	13.00	.26667*	.07794	.002	.1075	.4258
	14.00	.08333	.07794	.293	-.0758	.2425
	15.00	.03333	.07794	.672	-.1258	.1925
2.00	1.00	-.20000*	.07794	.016	-.3592	-.0408
	3.00	.15000	.07794	.064	-.0092	.3092
	4.00	-.15000	.07794	.064	-.3092	.0092
	5.00	-.20000*	.07794	.016	-.3592	-.0408
	6.00	-.18333*	.07794	.025	-.3425	-.0242
	7.00	-.05000	.07794	.526	-.2092	.1092
	8.00	-.01667	.07794	.832	-.1758	.1425
	9.00	.01667	.07794	.832	-.1425	.1758
	10.00	-.21667*	.07794	.009	-.3758	-.0575
	11.00	-.20000*	.07794	.016	-.3592	-.0408
	12.00	-.06667	.07794	.399	-.2258	.0925
	13.00	.06667	.07794	.399	-.0925	.2258
	14.00	-.11667	.07794	.145	-.2758	.0425
	15.00	-.16667*	.07794	.041	-.3258	-.0075
3.00	1.00	-.35000*	.07794	.000	-.5092	-.1908
	2.00	-.15000	.07794	.064	-.3092	.0092
	4.00	-.30000*	.07794	.001	-.4592	-.1408
	5.00	-.35000*	.07794	.000	-.5092	-.1908
	6.00	-.33333*	.07794	.000	-.4925	-.1742
	7.00	-.20000*	.07794	.016	-.3592	-.0408
	8.00	-.16667*	.07794	.041	-.3258	-.0075
	9.00	-.13333	.07794	.097	-.2925	.0258
	10.00	-.36667*	.07794	.000	-.5258	-.2075
	11.00	-.35000*	.07794	.000	-.5092	-.1908

	12.00	-.21667*	.07794	.009	-.3758	-.0575
	13.00	-.08333	.07794	.293	-.2425	.0758
	14.00	-.26667*	.07794	.002	-.4258	-.1075
	15.00	-.31667*	.07794	.000	-.4758	-.1575
4.00	1.00	-.05000	.07794	.526	-.2092	.1092
	2.00	.15000	.07794	.064	-.0092	.3092
	3.00	.30000*	.07794	.001	.1408	.4592
	5.00	-.05000	.07794	.526	-.2092	.1092
	6.00	-.03333	.07794	.672	-.1925	.1258
	7.00	.10000	.07794	.209	-.0592	.2592
	8.00	.13333	.07794	.097	-.0258	.2925
	9.00	.16667*	.07794	.041	.0075	.3258
	10.00	-.06667	.07794	.399	-.2258	.0925
	11.00	-.05000	.07794	.526	-.2092	.1092
	12.00	.08333	.07794	.293	-.0758	.2425
	13.00	.21667*	.07794	.009	.0575	.3758
	14.00	.03333	.07794	.672	-.1258	.1925
	15.00	-.01667	.07794	.832	-.1758	.1425
5.00	1.00	.00000	.07794	1.000	-.1592	.1592
	2.00	.20000*	.07794	.016	.0408	.3592
	3.00	.35000*	.07794	.000	.1908	.5092
	4.00	.05000	.07794	.526	-.1092	.2092
	6.00	.01667	.07794	.832	-.1425	.1758
	7.00	.15000	.07794	.064	-.0092	.3092
	8.00	.18333*	.07794	.025	.0242	.3425
	9.00	.21667*	.07794	.009	.0575	.3758
	10.00	-.01667	.07794	.832	-.1758	.1425
	11.00	.00000	.07794	1.000	-.1592	.1592

	12.00	.13333	.07794	.097	-.0258	.2925
	13.00	.26667*	.07794	.002	.1075	.4258
	14.00	.08333	.07794	.293	-.0758	.2425
	15.00	.03333	.07794	.672	-.1258	.1925
6.00	1.00	-.01667	.07794	.832	-.1758	.1425
	2.00	.18333*	.07794	.025	.0242	.3425
	3.00	.33333*	.07794	.000	.1742	.4925
	4.00	.03333	.07794	.672	-.1258	.1925
	5.00	-.01667	.07794	.832	-.1758	.1425
	7.00	.13333	.07794	.097	-.0258	.2925
	8.00	.16667*	.07794	.041	.0075	.3258
	9.00	.20000*	.07794	.016	.0408	.3592
	10.00	-.03333	.07794	.672	-.1925	.1258
	11.00	-.01667	.07794	.832	-.1758	.1425
	12.00	.11667	.07794	.145	-.0425	.2758
	13.00	.25000*	.07794	.003	.0908	.4092
	14.00	.06667	.07794	.399	-.0925	.2258
	15.00	.01667	.07794	.832	-.1425	.1758
7.00	1.00	-.15000	.07794	.064	-.3092	.0092
	2.00	.05000	.07794	.526	-.1092	.2092
	3.00	.20000*	.07794	.016	.0408	.3592
	4.00	-.10000	.07794	.209	-.2592	.0592
	5.00	-.15000	.07794	.064	-.3092	.0092
	6.00	-.13333	.07794	.097	-.2925	.0258
	8.00	.03333	.07794	.672	-.1258	.1925
	9.00	.06667	.07794	.399	-.0925	.2258
	10.00	-.16667*	.07794	.041	-.3258	-.0075
	11.00	-.15000	.07794	.064	-.3092	.0092

	12.00	-.01667	.07794	.832	-.1758	.1425
	13.00	.11667	.07794	.145	-.0425	.2758
	14.00	-.06667	.07794	.399	-.2258	.0925
	15.00	-.11667	.07794	.145	-.2758	.0425
8.00	1.00	-.18333*	.07794	.025	-.3425	-.0242
	2.00	.01667	.07794	.832	-.1425	.1758
	3.00	.16667*	.07794	.041	.0075	.3258
	4.00	-.13333	.07794	.097	-.2925	.0258
	5.00	-.18333*	.07794	.025	-.3425	-.0242
	6.00	-.16667*	.07794	.041	-.3258	-.0075
	7.00	-.03333	.07794	.672	-.1925	.1258
	9.00	.03333	.07794	.672	-.1258	.1925
	10.00	-.20000*	.07794	.016	-.3592	-.0408
	11.00	-.18333*	.07794	.025	-.3425	-.0242
	12.00	-.05000	.07794	.526	-.2092	.1092
	13.00	.08333	.07794	.293	-.0758	.2425
	14.00	-.10000	.07794	.209	-.2592	.0592
	15.00	-.15000	.07794	.064	-.3092	.0092
9.00	1.00	-.21667*	.07794	.009	-.3758	-.0575
	2.00	-.01667	.07794	.832	-.1758	.1425
	3.00	.13333	.07794	.097	-.0258	.2925
	4.00	-.16667*	.07794	.041	-.3258	-.0075
	5.00	-.21667*	.07794	.009	-.3758	-.0575
	6.00	-.20000*	.07794	.016	-.3592	-.0408
	7.00	-.06667	.07794	.399	-.2258	.0925
	8.00	-.03333	.07794	.672	-.1925	.1258
	10.00	-.23333*	.07794	.005	-.3925	-.0742
	11.00	-.21667*	.07794	.009	-.3758	-.0575

	12.00	-.08333	.07794	.293	-.2425	.0758
	13.00	.05000	.07794	.526	-.1092	.2092
	14.00	-.13333	.07794	.097	-.2925	.0258
	15.00	-.18333*	.07794	.025	-.3425	-.0242
10.00	1.00	.01667	.07794	.832	-.1425	.1758
	2.00	.21667*	.07794	.009	.0575	.3758
	3.00	.36667*	.07794	.000	.2075	.5258
	4.00	.06667	.07794	.399	-.0925	.2258
	5.00	.01667	.07794	.832	-.1425	.1758
	6.00	.03333	.07794	.672	-.1258	.1925
	7.00	.16667*	.07794	.041	.0075	.3258
	8.00	.20000*	.07794	.016	.0408	.3592
	9.00	.23333*	.07794	.005	.0742	.3925
	11.00	.01667	.07794	.832	-.1425	.1758
	12.00	.15000	.07794	.064	-.0092	.3092
	13.00	.28333*	.07794	.001	.1242	.4425
	14.00	.10000	.07794	.209	-.0592	.2592
	15.00	.05000	.07794	.526	-.1092	.2092
11.00	1.00	.00000	.07794	1.000	-.1592	.1592
	2.00	.20000*	.07794	.016	.0408	.3592
	3.00	.35000*	.07794	.000	.1908	.5092
	4.00	.05000	.07794	.526	-.1092	.2092
	5.00	.00000	.07794	1.000	-.1592	.1592
	6.00	.01667	.07794	.832	-.1425	.1758
	7.00	.15000	.07794	.064	-.0092	.3092
	8.00	.18333*	.07794	.025	.0242	.3425
	9.00	.21667*	.07794	.009	.0575	.3758
	10.00	-.01667	.07794	.832	-.1758	.1425

	12.00	.13333	.07794	.097	-.0258	.2925
	13.00	.26667*	.07794	.002	.1075	.4258
	14.00	.08333	.07794	.293	-.0758	.2425
	15.00	.03333	.07794	.672	-.1258	.1925
12.00	1.00	-.13333	.07794	.097	-.2925	.0258
	2.00	.06667	.07794	.399	-.0925	.2258
	3.00	.21667*	.07794	.009	.0575	.3758
	4.00	-.08333	.07794	.293	-.2425	.0758
	5.00	-.13333	.07794	.097	-.2925	.0258
	6.00	-.11667	.07794	.145	-.2758	.0425
	7.00	.01667	.07794	.832	-.1425	.1758
	8.00	.05000	.07794	.526	-.1092	.2092
	9.00	.08333	.07794	.293	-.0758	.2425
	10.00	-.15000	.07794	.064	-.3092	.0092
	11.00	-.13333	.07794	.097	-.2925	.0258
	13.00	.13333	.07794	.097	-.0258	.2925
	14.00	-.05000	.07794	.526	-.2092	.1092
	15.00	-.10000	.07794	.209	-.2592	.0592
13.00	1.00	-.26667*	.07794	.002	-.4258	-.1075
	2.00	-.06667	.07794	.399	-.2258	.0925
	3.00	.08333	.07794	.293	-.0758	.2425
	4.00	-.21667*	.07794	.009	-.3758	-.0575
	5.00	-.26667*	.07794	.002	-.4258	-.1075
	6.00	-.25000*	.07794	.003	-.4092	-.0908
	7.00	-.11667	.07794	.145	-.2758	.0425
	8.00	-.08333	.07794	.293	-.2425	.0758
	9.00	-.05000	.07794	.526	-.2092	.1092
	10.00	-.28333*	.07794	.001	-.4425	-.1242

	11.00	-.26667*	.07794	.002	-.4258	-.1075
	12.00	-.13333	.07794	.097	-.2925	.0258
	14.00	-.18333*	.07794	.025	-.3425	-.0242
	15.00	-.23333*	.07794	.005	-.3925	-.0742
14.00	1.00	-.08333	.07794	.293	-.2425	.0758
	2.00	.11667	.07794	.145	-.0425	.2758
	3.00	.26667*	.07794	.002	.1075	.4258
	4.00	-.03333	.07794	.672	-.1925	.1258
	5.00	-.08333	.07794	.293	-.2425	.0758
	6.00	-.06667	.07794	.399	-.2258	.0925
	7.00	.06667	.07794	.399	-.0925	.2258
	8.00	.10000	.07794	.209	-.0592	.2592
	9.00	.13333	.07794	.097	-.0258	.2925
	10.00	-.10000	.07794	.209	-.2592	.0592
	11.00	-.08333	.07794	.293	-.2425	.0758
	12.00	.05000	.07794	.526	-.1092	.2092
	13.00	.18333*	.07794	.025	.0242	.3425
	15.00	-.05000	.07794	.526	-.2092	.1092
15.00	1.00	-.03333	.07794	.672	-.1925	.1258
	2.00	.16667*	.07794	.041	.0075	.3258
	3.00	.31667*	.07794	.000	.1575	.4758
	4.00	.01667	.07794	.832	-.1425	.1758
	5.00	-.03333	.07794	.672	-.1925	.1258
	6.00	-.01667	.07794	.832	-.1758	.1425
	7.00	.11667	.07794	.145	-.0425	.2758
	8.00	.15000	.07794	.064	-.0092	.3092
	9.00	.18333*	.07794	.025	.0242	.3425
	10.00	-.05000	.07794	.526	-.2092	.1092

11.00	-.03333	.07794	.672	-.1925	.1258
12.00	.10000	.07794	.209	-.0592	.2592
13.00	.23333*	.07794	.005	.0742	.3925
14.00	.05000	.07794	.526	-.1092	.2092

*. The mean difference is significant at the 0.05 level.

WELLS

ONEWAY concentration BY sites /MISSING ANALYSIS /POSTHOC=LSD ALPHA(0.05).

Oneway

Notes

Output Created		18-Sep-2012 10:14:04
Comments		
Input	Data	C:\Users\Queenly\Documents\well2.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	33
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on cases with no missing data for any variable in the analysis.
Syntax		ONEWAY concentration BY sites /MISSING ANALYSIS /POSTHOC=LSD ALPHA(0.05).
Resources	Processor Time	0:00:00.047

Notes

Output Created		18-Sep-2012 10:14:04
Comments		
Input	Data	C:\Users\Queenly\Documents\well2.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	33
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on cases with no missing data for any variable in the analysis.
Syntax		ONEWAY concentration BY sites /MISSING ANALYSIS /POSTHOC=LSD ALPHA(0.05).
Resources	Processor Time	0:00:00.047
	Elapsed Time	0:00:00.063

[DataSet1] C:\Users\Queenly\Documents\well2.sav

ANOVA

Concentration

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.588	10	.059	6.936	.000
Within Groups	.187	22	.008		

ANOVA

Concentration

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.588	10	.059	6.936	.000
Within Groups	.187	22	.008		
Total	.775	32			

Post Hoc Tests

Multiple Comparisons

Concentration

LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	-.41667*	.07521	.000	-.5726	-.2607
	3.00	-.21667*	.07521	.009	-.3726	-.0607
	4.00	-.31667*	.07521	.000	-.4726	-.1607
	5.00	-.23333*	.07521	.005	-.3893	-.0774
	6.00	-.36667*	.07521	.000	-.5226	-.2107
	7.00	-.48333*	.07521	.000	-.6393	-.3274
	8.00	-.41667*	.07521	.000	-.5726	-.2607
	9.00	-.36667*	.07521	.000	-.5226	-.2107
	10.00	-.48333*	.07521	.000	-.6393	-.3274
	11.00	-.31667*	.07521	.000	-.4726	-.1607
2.00	1.00	.41667*	.07521	.000	.2607	.5726
	3.00	.20000*	.07521	.014	.0440	.3560
	4.00	.10000	.07521	.197	-.0560	.2560
	5.00	.18333*	.07521	.023	.0274	.3393

	6.00	.05000	.07521	.513	-.1060	.2060
	7.00	-.06667	.07521	.385	-.2226	.0893
	8.00	.00000	.07521	1.000	-.1560	.1560
	9.00	.05000	.07521	.513	-.1060	.2060
	10.00	-.06667	.07521	.385	-.2226	.0893
	11.00	.10000	.07521	.197	-.0560	.2560
3.00	1.00	.21667*	.07521	.009	.0607	.3726
	2.00	-.20000*	.07521	.014	-.3560	-.0440
	4.00	-.10000	.07521	.197	-.2560	.0560
	5.00	-.01667	.07521	.827	-.1726	.1393
	6.00	-.15000	.07521	.059	-.3060	.0060
	7.00	-.26667*	.07521	.002	-.4226	-.1107
	8.00	-.20000*	.07521	.014	-.3560	-.0440
	9.00	-.15000	.07521	.059	-.3060	.0060
	10.00	-.26667*	.07521	.002	-.4226	-.1107
	11.00	-.10000	.07521	.197	-.2560	.0560
4.00	1.00	.31667*	.07521	.000	.1607	.4726
	2.00	-.10000	.07521	.197	-.2560	.0560
	3.00	.10000	.07521	.197	-.0560	.2560
	5.00	.08333	.07521	.280	-.0726	.2393
	6.00	-.05000	.07521	.513	-.2060	.1060
	7.00	-.16667*	.07521	.037	-.3226	-.0107
	8.00	-.10000	.07521	.197	-.2560	.0560
	9.00	-.05000	.07521	.513	-.2060	.1060
	10.00	-.16667*	.07521	.037	-.3226	-.0107
	11.00	.00000	.07521	1.000	-.1560	.1560
5.00	1.00	.23333*	.07521	.005	.0774	.3893
	2.00	-.18333*	.07521	.023	-.3393	-.0274

	3.00	.01667	.07521	.827	-.1393	.1726
	4.00	-.08333	.07521	.280	-.2393	.0726
	6.00	-.13333	.07521	.090	-.2893	.0226
	7.00	-.25000*	.07521	.003	-.4060	-.0940
	8.00	-.18333*	.07521	.023	-.3393	-.0274
	9.00	-.13333	.07521	.090	-.2893	.0226
	10.00	-.25000*	.07521	.003	-.4060	-.0940
	11.00	-.08333	.07521	.280	-.2393	.0726
6.00	1.00	.36667*	.07521	.000	.2107	.5226
	2.00	-.05000	.07521	.513	-.2060	.1060
	3.00	.15000	.07521	.059	-.0060	.3060
	4.00	.05000	.07521	.513	-.1060	.2060
	5.00	.13333	.07521	.090	-.0226	.2893
	7.00	-.11667	.07521	.135	-.2726	.0393
	8.00	-.05000	.07521	.513	-.2060	.1060
	9.00	.00000	.07521	1.000	-.1560	.1560
	10.00	-.11667	.07521	.135	-.2726	.0393
	11.00	.05000	.07521	.513	-.1060	.2060
7.00	1.00	.48333*	.07521	.000	.3274	.6393
	2.00	.06667	.07521	.385	-.0893	.2226
	3.00	.26667*	.07521	.002	.1107	.4226
	4.00	.16667*	.07521	.037	.0107	.3226
	5.00	.25000*	.07521	.003	.0940	.4060
	6.00	.11667	.07521	.135	-.0393	.2726
	8.00	.06667	.07521	.385	-.0893	.2226
	9.00	.11667	.07521	.135	-.0393	.2726
	10.00	.00000	.07521	1.000	-.1560	.1560
	11.00	.16667*	.07521	.037	.0107	.3226

8.00	1.00	.41667*	.07521	.000	.2607	.5726
	2.00	.00000	.07521	1.000	-.1560	.1560
	3.00	.20000*	.07521	.014	.0440	.3560
	4.00	.10000	.07521	.197	-.0560	.2560
	5.00	.18333*	.07521	.023	.0274	.3393
	6.00	.05000	.07521	.513	-.1060	.2060
	7.00	-.06667	.07521	.385	-.2226	.0893
	9.00	.05000	.07521	.513	-.1060	.2060
	10.00	-.06667	.07521	.385	-.2226	.0893
	11.00	.10000	.07521	.197	-.0560	.2560
9.00	1.00	.36667*	.07521	.000	.2107	.5226
	2.00	-.05000	.07521	.513	-.2060	.1060
	3.00	.15000	.07521	.059	-.0060	.3060
	4.00	.05000	.07521	.513	-.1060	.2060
	5.00	.13333	.07521	.090	-.0226	.2893
	6.00	.00000	.07521	1.000	-.1560	.1560
	7.00	-.11667	.07521	.135	-.2726	.0393
	8.00	-.05000	.07521	.513	-.2060	.1060
	10.00	-.11667	.07521	.135	-.2726	.0393
	11.00	.05000	.07521	.513	-.1060	.2060
10.00	1.00	.48333*	.07521	.000	.3274	.6393
	2.00	.06667	.07521	.385	-.0893	.2226
	3.00	.26667*	.07521	.002	.1107	.4226
	4.00	.16667*	.07521	.037	.0107	.3226
	5.00	.25000*	.07521	.003	.0940	.4060
	6.00	.11667	.07521	.135	-.0393	.2726
	7.00	.00000	.07521	1.000	-.1560	.1560
	8.00	.06667	.07521	.385	-.0893	.2226

	9.00	.11667	.07521	.135	-.0393	.2726
	11.00	.16667*	.07521	.037	.0107	.3226
11.00	1.00	.31667*	.07521	.000	.1607	.4726
	2.00	-.10000	.07521	.197	-.2560	.0560
	3.00	.10000	.07521	.197	-.0560	.2560
	4.00	.00000	.07521	1.000	-.1560	.1560
	5.00	.08333	.07521	.280	-.0726	.2393
	6.00	-.05000	.07521	.513	-.2060	.1060
	7.00	-.16667*	.07521	.037	-.3226	-.0107
	8.00	-.10000	.07521	.197	-.2560	.0560
	9.00	-.05000	.07521	.513	-.2060	.1060
	10.00	-.16667*	.07521	.037	-.3226	-.0107

*. The mean difference is significant at the 0.05 level.

F-Test Two-Sample for Variances wells and boreholes

	Variable 1	*Variable 2*
Mean	0.984091	1.062121
Variance	0.017881	0.024223
Observations	44	33
df	43	32
F	0.738149	
P(F<=f) one-tail	0.174982	
F Critical one-tail	0.58422	

F-Test Two-Sample for Variances wells and river

	Variable	*Variable 2*

	1	
Mean	0.984091	0.366667
Variance	0.017881	0.005833
Observations	44	3
df	43	2
F	3.065237	
P(F<=f) one-tail	0.276597	
F Critical one-tail	19.47248	

F-Test Two-Sample for Variances

borehole and wells

	Variable 1	*Variable 2*
Mean	1.075	0.366667
Variance	0.019355	0.005833
Observations	32	3
df	31	2
F	3.317972	
P(F<=f) one-tail	0.258067	
F Critical one-tail	19.46349	

Chi square test.

	Male	Female	Total
Actual	66	54	120
Expected	60	60	120

0.273322

age	male	female	total
12	10	20	30
13	13	9	22
14	17	15	32
15	26	10	36
	15	15	
	11	11	
	16	16	
	18	18	

0.010225

APPENDIX B:

QUESTIONNAIRES FOR THE DETERMINATION OF FLUOROSIS

Age: **Sex**: M [ ] F [ ]

Type of drinking water: Borehole [ ] well [ ] River [ ]

Category of fluorosis:

Unaffected [ ]

Questionable [ ]

Very mild [ ]

Mild [ ]

Moderate [ ]

Severe [ ]