# Assessment of the Impact of Groundwater Fluoride on Human Health in Makindu District, Makueni County, Kenya

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**A thesis submitted in partial fulfillment of the requirement for the award of the degree of Master of Science in Environmental Management in the School of Environment and Natural Resources Management of South Eastern Kenya University.**

**2017**

**DECLARATION**

I understand that plagiarism is an offence and therefore declare that this thesis is my original work and has not been presented to any other institution for any other award.

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## DEDICATION

This thesis is dedicated to my dear loving husband, Anthony Mutinda, who has had to sacrifice a lot to see to it that I have gone through this study successfully. Special dedication also goes to my dear sons Mark Mutinda and David Mutinda - may you grow to be diligent scientists who reverence the God of Israel. May God richly bless you all.

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**ABSTRACT**

Assessment of human exposure to the naturally occurring fluoride in groundwater in Kenya has not being exhaustive in terms of geographical coverage and the media. There is need to have representative data and information on the extent of human exposure to fluoride and its impact on human health. This study investigated the extent of human exposure to fluoride and its impact on human health in Makindu District, and evaluated the potential risk of using ground water contaminated by fluoride ion ($F^-$). The study used, an ex post facto design and the data collection tools used were interviews, questionnaires, key informants and observation. The research involved three key-informants, two dentists and one health officer, a sample of 286 respondents from Makindu Location and 112 respondents from Kiboko Location were interviewed and observed. The data collected was analyzed using the Ms-Exel and the Statistical Package for Social Sciences (SPSS). Majority, 80% and 68% respectively, of the respondents in Makindu Location and Kiboko Location relied on tap water from springs whereas those who relied on boreholes were 10% and 21% respectively. Raw water from Makindu Spring, the main source of drinking water for Makindu Town, had fluoride concentration of 1.1 mg/L, which is below the WHO maximum allowable value of 1.5 mg/L. All the three boreholes covered during the study had fluoride concentration above the WHO maximum allowable value with Kiboko Borehole having the highest concentration of 4.2 mg/L followed by Makindu Boys Borehole with concentration of 2.85 mg/L. This implied that the population that relied on boreholes as a source of water was exposed to health risk associated with high fluoride. 38.4% and 33.3% of the respondents, respectively from Kiboko Location and Makindu Location, had moderately to severely mottled enamel, an indication of the impact of fluoride in water. To mitigate for the health impact of high fluoride, use of alternative sources of potable water as well as defluoridation is recommended. In addition, educating the community on dangers of using water with excess fluoride is recommended in order to ensure good health.

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## DEFINITION OF OPERATIONAL TERMS

| | |
|---|---|
| **Ca** | Calcium |
| **DNA** | Deoxyribonucleic Acid |
| **F** | Fluorine |
| **$F^-$** | Fluoride Ion |
| **IARC** | International Agency for Research on Cancer |
| **IGRAC** | International Groundwater Resources Assessment Centre |
| **MAWASCO** | Makindu Water and Sewerage Company |
| **Mg** | Magnesium |
| **NCHS** | National Centre for Health Statistics |
| **NTP** | National Toxicology Programme |
| **UNESCO** | United Nations Educational, Scientific and Cultural Organization |
| **WHO** | World Health Organization |
| **WWAP** | World Water Assessment Programme |

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background of the Study

Water is life. Without water, man's existence on earth would be driven close to extinction. All biological organisms depend on water to carry out complex biochemical processes which aid in the sustenance of life on earth. Over 70% of the earth's surface materials consist of water and apart from air that man breathes, water is one of the most important compounds to man. Though water covers about 70% of the earth's surface, only 2.53% is fresh water while the remaining is salt water (UNESCO, 2003:8). Of the fresh water, 68.7% is glaciers, 30.1% groundwater, 0.8% permafrost and 0.4% surface and atmospheric water (WWAP 2006).

Fluoride is an ion of the chemical element fluorine which belongs to the halogen group. Fluoride has a significant mitigating effect against dental caries if the concentration is approximately 1.0mg/L (Fleischer et al, 1974). However, continuing consumption of higher concentrations can cause dental fluorosis. High fluoride concentrations are especially critical in developing countries, largely because of lack of suitable infrastructure for treatment (Muller, 2005). Fluoride is a common constitute of ground water. Natural sources are connected to various types of rocks and to volcanic activities (Frencken, 1992). However, industrial activities such as clay used in ceramic industrial activities or burning of coals can also contribute to high fluoride concentrations in ground water.

#### 1.1.1 Occurrence of Fluoride

Fluorine is the ninth element of the periodic table. Nevertheless, its applications and biological significances were known only in the decades of 1920's. It is the lightest member of the halogen family and the most electronegative among all chemical elements

(Hodhe and Smith, 1965). Fluorine has both notable chemical qualities and physiological properties, which are of great interest and significance to human health. Fluorine is rarely or never found free in nature in elemental form. It has strong affinity to combine chemically with other elements to form compounds called ‘fluorides’. Free fluorine plays no part in toxicology because it reacts immediately to form fluoride compounds. The presence of dissolved fluorides in natural water is possible only when conditions favor long residence time of the F-species in solution (Fawel et al. 2006).

Fluoride occurs naturally in public water systems as a result of run off from weathering of fluoride containing rocks and soils leaching from soil into groundwater. Atmospheric deposition of fluoride containing emissions from coal fired power plants and other industrial sources can also contributes to amounts found in the water, either by direct deposition or by deposition to soil and subsequent runoff into water (Frencken, 1992)

The only rocks forming minerals that have fluorine as an essential constituent in the formula are topaz and fluorite. The other minerals in which fluorine is an essential component are accessory minerals- fluorapatite, fluomical, (phlogopite), cryolite, and villiaumite. These fluoride minerals are sparingly soluble in water. (Clarke et al. 1992; Allen and Darling, 1992).

Awareness of the environmental problem of fluoride in drinking water has been increased by the fact that skeletal abnormalities and dental fluorosis can be related to the level of fluoride intake (shape et al., 1979; Chaturredi et al., 1988).In Kenya, cases of dental caries and dental fluorosis (Gitonga and Nair, 1982) have been related to the amount of fluoride consumed mainly from drinking water, which for a large number of communities is obtained directly from boreholes or streams.

## 1.2 Statement of the Research Problem

Representative data and information on the impacts of fluoride on human health in many parts of the world including Kenya is inadequate. This makes it difficult to arrive at global values on the ill-effect related to consumption of ground water contaminated with fluorine (Frencken et al., 1992).

Makindu District being in arid and semi-arid area, Calcium and Magnesium/ carbonate concentration are high in the soils and rocks and appear to be good sink for the fluoride ion (Jack et al., 1980). Makindu District like any other arid region is prone to high fluoride concentrations. Here, groundwater flow is slow and the reaction times with rocks are therefore long. The fluoride contents of solution in water may increase during evaporation if solution remain in equilibrium with calcite and alkalinity is greater than hardness. Dissolution of evaporative salts deposited in arid zones may be an important source of fluoride (Frencken et al., 1992).

Little is reported on the impacts on the human exposure to the fluoride particularly the local community and general public in Makindu District. The problem with continuing consumption of higher concentration of fluoride can cause dental fluorosis and in extreme cases skeletal fluorosis (Muller, 2005). Research is therefore necessary in Makindu District, Makueni County, to provide information and representative data to the relevant environmental and health authorities, add to scholarly knowledge as well as create awareness among the general public about the impacts on human health caused by the fluoride in the environment.

## 1.3 Purpose of the Study

Investigations on groundwater pollution or contamination with fluoride and its impacts on human health have received particular attention worldwide through intensive surveys in many countries (IPCS, 2002). This subject has not received enough attention in Kenya although a few studies on occurrence and distribution of fluoride in groundwater of

Kenya have been reported (Allen and Darling, 1992). Some of the benefits derived from these studies include; generation of information and data required for evaluating the impacts of groundwater fluoride on human health in Makindu District. An understanding of the exposure time to groundwater fluoride pollution is important because longer exposure time can cause adverse health effects to the exposed human population and animals in these areas. Environmental authorities will use the findings of this study to educate the human population on dangers of exposing themselves to groundwater fluoride and possible mitigation measures to save them from the impacts of naturally occurring fluoride. Data obtained will form background information for further studies on groundwater contaminated with fluoride in other parts of the country with the same geology. It is envisaged that the results of this study will be useful to the relevant scientific committees, governmental and non-governmental organizations such as WHO, and the International Groundwater Resources Assessment centre (IGRAC) in making important decisions about groundwater contaminated with fluoride.

## 1.4 Objectives

### 1.4.1 General Objective

The general objective of this study was to investigate the exposure levels to fluoride in groundwater and its impact on human health in Makindu District, Makueni County.

### 1.4.1 Specific Objectives

The specific objectives of this study were:-

1. To investigate whether the human population in Makindu District is exposed to fluoride in groundwater.
2. To determine the extent of the exposure of fluoride to the human population in Makindu District.
3. To assess the impact of fluoride in drinking water to human population in Makindu District

4. To determine the possible mitigation measures against the ill effects of fluoride in ground water to Makindu District.

## 1.6 Research Questions

This study was guided by the following research objectives.

1. Is the human population in Makindu District exposed to fluoride in groundwater?
2. To what extent is the human population in Makindu District exposed to fluoride in ground water?
3. What are the impacts of fluoride in drinking water to human population in Makindu District?
4. What are the possible mitigation measures against the ill effects of fluoride in groundwater in Makindu District?

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Introduction

Endemic fluorosis in Kenya has been a public health problem for many years (Manji and Kapila, 1984) and now there is heightened public health concern about the fate of fluoride (F) in soil and ground water sources, particularly in areas associated with the Great Rift valley and the central Highlands (Sudhir and Bashir, 2006). In addition, rapid population growth and changes in rainfall patterns in many parts of Kenya has exacerbated the problem of water scarcity (Imbernon, 1999), forcing communities to turn to poor quality water sources for their needs (showers, 2002).

Primary sources of water for rural population in Kenya are rivers, streams, springs and wells in watered areas and boreholes in arid and semi-arid regions. Piped water is limited to urban areas (Gikunju et al., 2002). Communities in rural areas use water from natural sources without treatment, and water monitoring is not possible because many rural areas are relativelyinaccessible. Thus, in recent studies, it has been proposed that more fluoride surveys should be conducted to establish the risk posed by increasing fluoride exposure in certain communities (Gikunju et al., 2002). Therefore, investigation to determine the fluoride levels in domestic water sources of the Makindu District population to evaluate the potential risk of fluorosis to people using their waters is of paramount importance.

### 2.2 Sources of Fluoride in the Environment

The cycle of fluoride throughout the bio geosphere is summarized in figure 2.1 below. The fluoride cycle refers to the way in which fluoride compounds circulate in nature. It mainly involves a continuous exchange of fluoride ions between living and non-living things. Fluorine always occurs in combined form of minerals as fluoride. It is highly reactive and represents about 0.06 to 0.09% of the earth crust (WHO, 1984). The presence of fluorine in the groundwater is mainly a natural phenomenon, and mainly influenced by local and regional geological conditions, as the fluoride minerals are nearly insoluble in water. Hence fluorine is present in groundwater only when the conditions favor their solution.

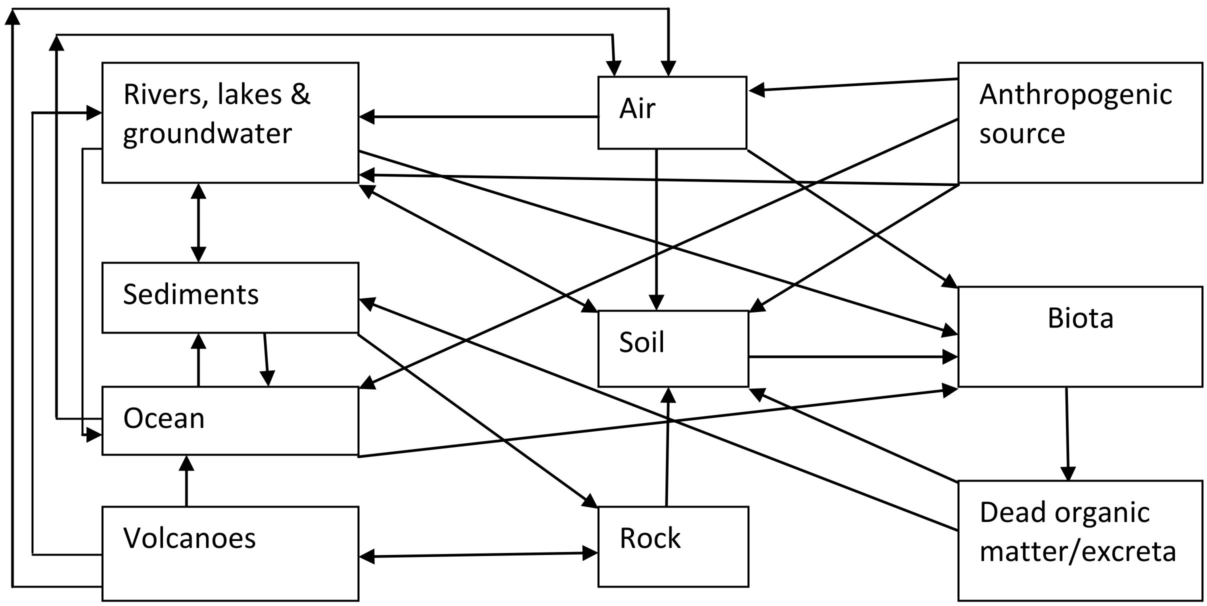



**Fig.2.1** Fluoride Biogeocycle (Adopted from: Connett, 2002)

The main source of fluorine in groundwater is basically from the mafic minerals shown in the Table 2.1. These minerals are commonly associated with the country rocks through which the groundwater percolates under variable temperature conditions.

**Table 2.1:** The value of fluoride in various rock types (From: Saggerson, 2000)

| Rocks | Fluoride range(in PPM) | Average(in PPM) |
|---|---|---|
| Basalt | 20-1060 | 360 |
| Granites and Gneisses | 20-2700 | 870 |
| Shales and Clay | 10-7600 | 800 |
| Limestones | 0-1200 | 220 |
| Sandstones | 10-880 | 180 |
| Phosphorite | 2400-41500 | 31000 |
| Coals(ash) | 40-480 | 80 |

Besides these minerals, alkali rocks, hydrothermal solutions may also contribute to higher concentration of fluoride in groundwater. Saggerson (2000) reported that the main source of fluorine in ordinary soils consists of clay minerals. The weathering and leaching process, mainly by moving and percolating water, play an important role in the incidence of fluoride in groundwater. The factors related to the release of fluoride bearing minerals may include:

i. The chemical composition of water
ii. The presence and accessibility of fluoride minerals to water
iii. The contact time between the source minerals

Fluoride rich minerals, which are present in rocks and soil, when they come into contact with water of high alkalinity, release fluoride into groundwater through hydrolysis replacing hydroxyl Ion. The degree of weathering and leachable fluoride in terrain is more important in determining the fluoride bearing minerals in the bulk rocks or soil. Due to weathering of rocks, the Calcium and Magnesium Carbonate concentration which form in arid and semi-arid areas appears to be good sink for the fluoride ion (Jack et al., 1980). The factors that control the leachability to fluoride from carbonate concentration or from the top soil horizon may be:

i. The PH of the draining solution
ii. The dissolved carbon IV oxide in water and in the soil
iii. Alkalinity

Besides these factors, the topographic features may also play an important role in the control of fluoride content as suggested by Rameshan and Rajagopalan (1985). The existence of some of the basic dykes such as doleritic intrusions normally acts as natural barriers against the flow of underground water making the groundwater stagnate in fractures and pores. If the groundwater is more alkaline and stagnant for a longer time, all the fluoride minerals in basic dyke rocks, and the overlying soils that are rich in mafic minerals undergoe greater ionization facilitating the groundwater get enriched with fluoride. The degree of ionization increases with depth resulting in an increase in total dissolved salts and alkalinity. The rocks are the natural aggregation of minerals and contain fluoride in abundant quantity. Soil is also rich in fluoride bearing minerals (Keller, 1976).

Rarely, natural waters (mainly groundwater of arid regions) may contain fluoride concentrations greater than 10mg/l. Fluoride may also be added to drinking water to assist in control of dental caries. Such additions require close control of fluoride concentrations to roughly 1.0Mg/l, as higher levels can cause mottling of the teeth. The guideline value of 1.5Mg/l in drinking water has been proposed by WHO. The local application of this value must take into account the climatic conditions and levels of water consumption. Mottling of teeth has been classed in the USA as a cosmetic effect, but maximum limit of 4Mg/l fluoride has been set to prevent skeletal fluorosis (a crippling condition that can result from excessive fluoride intake).

Fluoride is used in certain industrial processes and consequently occurs in the resulting wastewaters. Significant industrial sources of fluoride are production of coke, glass and ceramics, electronics, steel and aluminium processing, pesticides and fertilizers and electroplating operations. Waste levels may range from several hundred to several thousand milligrams per liter in untreated wastewaters. It is worthy of note that conventional treatment (lime) seldom reduces fluoride concentrations below 8-15Mg/l without dilution. (Reardon and Wang, 2000).

As for foods it has been shown that vegetables and fruits have low levels of fluoride with ranges of 0.1-0-4Mg/Kg (WHO, 2004). Foods with higher levels of fluoride consist of barley and rice with about 2Mg/kg of fluoride. Fish can contain fluoride levels of ranges 2-5Mg/kg, however, canned fish and fish protein concentrations may contain fluoride levels up to 370Mg/kg (IPCS, 2002). Dry tea leaves also have significantly high levels of fluoride up to 400 Mg/kg. However due to ingestion of tea the fluoride exposure ends up ranging from 0.04-2.7Mg/person/day (Murray, 1986). In one study that was done, it was shown that 34% of fluoride in black tea remains in the oral cavity (Sympson *et. al* 2001). Toothpaste contains very high levels of fluoride up to 1000-1500Mg/kg of toothpaste; however, what is accidentally swallowed and ingested may range up to 3.5Mg/day. It has been shown that with all the human exposure to fluoride that varies from region to region, drinking water is generally on average the largest single contributor to daily fluoride intake (Murray, 1986). Due to this fact, daily fluoride intakes (mg/kg of body weight) are based on fluoride levels in water and water consumption per day per liter.

### 2.3 Fluoride Content of Kenyan Waters

There is wide variation in fluoride levels in the natural waters of Kenya (Table 1) concentrations above and below the optimal range set by the World Health Organization for drinking water, i.e. 0.7-1.5 ppm (WHO, 1984) are encountered. River waters generally have fluoride contents in the lower part of this range whereas ground waters show much higher levels (Bakshi, 1974; Njenga, 1982). Lake waters carry by far the highest fluoride concentrations recorded for Kenyan waters, with the contents in the alkaline and saline lakes greater than in relatively fresh-water lakes (Table2.2).

With regard to ground waters, several patterns in fluoride behavior have been observed.
High fluoride concentrations are obtained in discharge areas than in recharge areas, with a trend of fluoride enrichment along the direction of flow. This has been attributed to the

smaller quantities of dissolved solids in the recharge areas of groundwater compared with the discharge areas (Maina, 1982; Nanyaro *et al*., 1984). Fluoride levels in water samples from boreholes have also been found to be related to both depth (Njenga, 1982) and location (Njenga, 1982; Mailu, 1983).

**Table 2.2**: Fluorine Concentration of Some Natural Waters of Kenya

| Source | Sample Description | Fluoride(ppm) | Reference |
|---|---|---|---|
| Nairobi rivers | River samples | 0.12-14.0 | Njenga (1982) |
| Kiambu | Boreholes | 0.15-0.35 | Njenga (1982) |
| Athi Basin | Boreholes | 0.1-12 | Mailu (1983) |
| Nakuru | Boreholes | 25 | Njenga(1982) |
| Lake Turkana | Lake | 21 | Allen and Darling (1992) |
| Kapendo | Hot springs | 27-29 | Allen and Darling (1992) |
| Logipi | Hot springs | 110 | Allen and Darling (1992) |
| Churo | Cool springs | 1.1-1.2 | Allen and Darling (1992) |
| Lake Baringo | Lake | 6.3 | Allen and Darling (1992) |
| Mandera District | Boreholes | 0.3-2.0 | Allen and Darling (1992) |

The highest amount of rainfall in Kenya's, at least that part which does not evaporate, passes through the surface soil and is stored underground. Groundwater is thought to form the major source of water for majority of Kenya's population. Though the country is well supplied with numerous rivers and streams, most contain water only during the rainy seasons (Ojany, 1974). Access to ground water is made by digging holes in river beds, or by drilling wells and boreholes (of which there are several hundreds in Kenya). (Ojany, 1974)

All urban centers have improved water supply systems but in many cases, including the capital city Nairobi, these are not sufficient to supply all the inhabitants (Gitonga and

Nair, 1982). For this reason the peripheral population of the urban areas is in a similar situation to those in the rural areas, being dependent on supplies of untreated water.

In Kenya, the only treatment carried out on groundwater is chlorination for urban supplies and no treatment is provided for rural water supplies with boreholes as a source. For surface waters where there is visible turbidity, full treatment is provided; such treatment includes coagulation and flocculation with lime, sedimentation, filtration, chlorination and pit adjustment (Gitonga and Nair, 1982).

The first attempt to study the occurrence and distribution of fluoride ion concentration in ground water in Kenya was by Williamson (1953). The study examined results available from analyses carried out by the Government chemist of fluoride levels in borehole waters. In some areas extremely high levels of fluoride ion concentrations were reported; for example the highest levels in wells was 39.0 ppm, in, 43.50 ppm, in Lake Elementaita 1640 ppm and in Lake Nakuru 2800 ppm.

## 2.4 Fluoride Occurrence in Africa

High fluoride levels occur in ground water in some parts of Tanzania, Malawi and The Republic of South Africa; however, the East African Countries have higher levels compared to the Southern countries. In Tanzania for example, fluoride concentrations in ground water of up to 40mg/l have been reported (Table 2.3).

Tanzanian Lake Momella is reported to have a fluoride concentration of 690 mg/l (Fawell et al. 2006) and concentration of up to 45 mg/l have been detected in the rift valley. The most affected areas of Tanzania are Mwanza, Mara, Shinyanga, Arusha, Kilimanjaro and Singida. Fluoride occurrence in groundwater in Malawi has been better surveyed in the Southern region (Thole, 2005; Masamba et al., 2005; and Sajidu et al., 2008).

**Table 2.3** Fluoride concentrations in some ground water sources in Northern Tanzania (Mjengera and Mkonga, 2003)

| Location | Average fluoride level (mg/L) |
|---|---|
| ArushaMajiya chai ,Arumeru District | 20.0 |
| Lemongo spring | 10.5 |
| Kikati B/H/13/79 | 11.0 |
| MasaiFurrow-Tingatinga | 32.0 |
| B/H 186/81-Hanang | 46.0 |
| Singida S/W 8/78-Ngorongoro | 11.6 |
| Senene | 10.5 |
| Well Camp Doromoni | 21.5 |
| Fish camp Migilango village | 12.5 |
| Hot Spring –Manyoni | 10.5 |
| Shinyanga S/W Mkololo | 17.0 |

Research in the Republic of South Africa has shown that underground mine waters may contain high fluoride levels beyond 3mg/l. In one selected case fluoride levels of about 6mg/l were identified in groundwater of Madibeng. Areas affected include the North – West provinces, the Karoo, Limpopo and the Northern cape. Cases like these have attracted research in water defluoridation such that evaluation of activated alumina as a defluoridating agent was carried out (Manguhan-Brown, 1935, and McCaffrey and Willis, 1997; Chikte et_al., 2001).__The researches demonstrated that the activated alumina could be employed to treat underground mine water with initial fluoride levels as high as 8mg/L. Two defluoridation plants were installed with capacity of 500,000 litres/day each in the early 1980$^{s}$in the Republic of South Africa (Chikte et al. 2001).

## 2.5 Fluoride Occurrence in the World

Geogenic occurrence of fluoride is often linked to volcanic activity, fumaric gases and presence of thermal waters. Proxy indicators of high fluoride levels in groundwater are;

low levels of calcium and magnesium, high levels of sodium and bicarbonate ions, and high PH above 7. Areas with high fluoride in groundwater include fluoride beds encompassing parts of Iraq, Iran, Syria, Turkey, Algeria, Morocco and the East African rifts system extending from Jordan Valley down through Sudan, Ethiopia, Uganda, Kenya and Tanzania. There are high fluoride areas in other parts of the world such as Central Asia, North and Central America, Oceania, South America and in Europe (Brunt et al., 2004).

### 2.6 Effect of Fluoride on Human Health.

Fluoride contamination is a major health hazard in many parts of the world but is considered beneficial to human health if taken in limited quantity (0.5 to 1.5Mg/L). Fluoride prevents tooth decay by enhancing the remineralization of enamel that is under attack, as well as inhibiting the production of acid by decay causing bacteria in dental plaque. Fluoride is also a normal constituent of the enamel itself, incorporated into the crystalline structure of the developing tooth and enhancing its resistance to acid dissolution. But it is also known to cause dental and skeletal fluorosis, Osteosclerosis, thyroid, kidney changes and cardiovascular, gastrointestinal, endocrine, neurological, reproductive, developmental, molecular level, immunity effects if concentration is higher than 1.5mg/l in drinking water (WHO, 1996).Smith and Hodge, (1959) have shown the correlation between fluoride and biological effect (Table 2.4).

**Table 2.4:** The effects of fluoride concentration on biological and human health (Adopted from Smith and Hodge, 1959)

| Fluoride Concentration | | Effect |
|---|---|---|
| 1. | 0.002 mg/L (in air) | Injury to vegetation |
| 2. | 1 mg/L (in water) | Dental Caries Reduction |
| 3. | >2 mg/L (in water) | Mottled enamel |
| 4. | 3.1 to 6.0 mg/L (in water) | Osteoporosis |
| 5. | 8 mg/L (in water) | 10% Osteoporosis |
| 6. | 20-80 mg/day (more in water or air) | Crippling skeletal fluorosis |
| 7. | 50 mg/L (food or water) | Thyroid change |
| 8. | 100 mg/L (in food or water) | Growth retardation |
| 9. | >125 mg/L (in food or water) | Kidney change |
| 10. | 2.5- 5.0 gm in actual dose | Death |

### 2.6.1 Effect on Dental Enamel

Dental fluorosis is a condition that results from the intake of excess levels of fluoride during the period of tooth development, usually from birth to approximately 6-8 years of age. It has been termed as hypoplasia or hypomineralization of dental enamel and dentine and is associated with the excessive incorporation of fluoride into these structures. The severity of this condition, generally characterized as ranging from very mild to severe, is related to the extent of fluoride exposure during the period of tooth development. Mild dental fluorosis is usually typified by the appearance of small white areas in the enamel; individuals with severe dental fluorosis have teeth that are stained and pitted ("mottled") in appearance. In human fluorotic teeth, the most prominent feature is a hypomineralization of the enamel. The staining and pitting of fluorosed dental enamel are both post eruptive phenomena (i.e, acquired after tooth eruption and occur as a consequence of the enamel hypomineralization).

The incorporation of excessive amounts of fluoride into enamel is believed to interfere with its normal maturation, as a result of alterations in the rheological structure of the enamel matrix and/or effects on cellular metabolic processes associated with normal enamel development (WHO, 1984; Aoba, 1997; Whitford, 1997). Experimental animal studies suggest that this hypomineralization results from fluoride disturbance of the process of enamel maturation (Richards et al., 1986).

Dental fluorosis is caused in human being consuming water containing 1.5mg/1 or more fluoride, particularly from birth to the age of eight. Mottled enamel usually takes the shape of modification to produce yellow brown stains or an unnatural opaque chalky white appearance with occasional striations patting. The incidence and severity of mottling was found to increase with increasing concentration of fluoride in drinking water (Dean, 1942). In extensive studies, Dean and co-workers (Elvove, 1937) have correlated the appearance and severity of dental fluorosis to different fluoride levels in the drinking water with the aid of a special classification and weighing of severity of the lesion (Table 5).

**Table 2.5** Correlation of appearance and severity of Dental Fluorosis (Dean, 1942)

| **Level Dental Fluorosis** | **Appearance** |
|---|---|
| Normal | The enamel presents translucent, semi-vitriform type of structure. The surface is smooth, glossy and usually pale creamy white colour |
| Questionable | Seen in area of relatively high endemicity, occasional cases are borderline and one would hesitate to classify them as apparently normal or very mild |
| Very mild | Small, opaque paper-white area seen, scattering irregularly over the labial and buccal surfaces |
| Mild | The white opaque areas involve at least half of the tooth surface and faint brown stains are sometimes apparent |
| Moderately | Generally all tooth surfaces are involved and minute pitting is often present on the labial and buccal surfaces. Brown stain is frequently a disfiguring complication. |
| Moderately severe | Pitting is marked, more frequent and generally observed on all tooth surfaces. Brown stains present are generally of greater intensity |

| | |
|---|---|
| Severe | The severe hypeoplasic affect the form of the teeth and stains are wide spread, and vary in intensity from deep brown to black. |

Distribution of dental fluorosis at different levels of fluoride in drinking water may be assessed by a mottled enamel index of the community, which is defined in terms of the degree of severity of mottled enamel observed clinically.

M

Severe

**Fig 2.2** Examples of enamel affected differently by fluoride (From: https://www.google.com)

Fluoride above 4mg/l in drinking water may cause a condition of dense and brittle bones known as Osteoporosis. It affects tens of millions of people worldwide and is responsible for as many as 75% of all fractures in people over the age of 45. Costly and disabling fractures of spine, hip, wrist and other bones can be preceded by years of undetected bone loss. It is found that as many as 20% of those who suffer from Osteoporosis related hip fractures die within 6 months. Women are at four times greater risk of developing Osteoporosis than males (Bezerra et al., 2003).

The chronic toxic effect of fluoride on the skeletal system have been described from certain geographical regions of the world where drinking water contains excessive quantities of natural fluoride. This form of chronic intoxication was first described in India from the state of Madras as early as 1937 (short et al., 1937). Subsequently cases of endemic fluorosis have been reported from other parts of India, particularly from Punjab(Singh et al., 1962 a, b, 1963) and sporadically from other parts of the world, notably Ceylon (Clark, 1942), China (Lyth, 1946), Japan (Hamamoto et al., 1954), Saudi Arabia (El, Tannir, 1959), USA,(Leone et al., 1954; Zipkin et al., 1958) Canada (Kilborn et al., 1950) and Europe (Odenthal and Wieneke, 1959). Besides endemic fluorosis, chronic toxic effects of fluoride on the skeletal system have also been observed in relation to industrial exposure to fluorides such as cryolite and in fact it is the pioneer studies of Roholm (1937) that paved the way for further contributions on the subject.

At higher levels of Ingestion from 2 to 8mg daily when signs of fluorosis appear in teeth mineralized during the Ingestion period, certain other factors (climatic conditions, Malnutrition, age, storage, other constituents of water and possibly individual variations in absorption) may be involved. Under such conditions and over a number of years, skeletal fluorosis may arise characterized by an increased density of bone and demonstrated in adults radio graphically (Yildiz et al., 2003). The data put forward by McClure *et al*., (1945), although no longer regarded as accurate indicate that the limit of total fluoride which may be ingested daily without hazardous body storage is of order of 4-5mg daily.

Fluoride replaces hydroxides and deposited in bones causing chronic effect known as skeleton fluorosis. The dental and skeletal changes in endemic fluorosis provide important clinical diagnostic criteria. Whereas dental fluorosis is easily recognized but the skeletal involvement is not clinically obvious until the advanced stage of crippling fluorosis. However, radiological changes are discernible in the skeleton at a much earlier stage and provide the only means of diagnosing the early and relatively asymptomatic stages of fluorosis (Connett, 2002; Lavy, 2003).

Such early cases are usually in young adults where only complaints are vague pains noted most frequently in the small joints of the hands and feet, in the knee joints and in the joint of spine. These cases are frequent in the endemic areas and may be misdiagnosed as rheumatoid or Osteoarthritis. In later stages, there is an obvious stiffness of the spine with limitation of movement and still later, the development of Kyphosis. There is difficulty in walking due partly to stiffness and limitation of the movements of various joints and partly to the neurological lesions of advanced cases. Similarly, some of the patients complain of dysphoeaon exertion because of the rigidity of the thoracic cage. In Roholm's series of industrial fluorosis cases, the gastrointestinal symptoms of lack of appetite, nausea, and constipation were as frequent as the symptoms of stiffness of joints, but the former have not been described in the different studies of endemic fluororois.

The advanced stage of fluoride intoxication results from the continuous exposure of an individual to 20-80mg of fluoride ion daily over a period of 10-20 years. Such heavy exposure is associated with a level of at least 10mg/l in drinking water supply. The crippling deformities are due partly to mechanical factors and partly to the immobilization necessitated by pain and paraplegia. The commonest deformities are Kyphosis, flexion deformity of the hips, flexion deformity of the knees and fixation of the chest in the position of inspiration due to calcification of cartilages. The quadriplegic patient bent with Kyphosis and with restricted movements of his spine, with contractures of hips and knees (Kaminsky et al., 1990).

### 2.6.2 Cardiovascular Effects

The cardiovascular effects of fluoride have been attributed to hypocalcaemia caused by high fluoride levels. Fluoride can bind with serum calcium if the dose is sufficient and cause hypocalcaemia. Calcium is necessary for the functional integrity of the voluntary and autonomic nervous systems. Hypocalcaemia can cause tetany, decreased myocardial contractility, and possibly cardiovascular collapse (Bayless and Tinanoff, 1985). Hyperkalemia has been suggested as the cause of the repeated episodes of ventricular fibrillation and eventual death that are often encountered in cases of fluoride poisoning (Baltazar et al., 1980).

### 2.6.3 Gastrointestinal Effects

The primary gastrointestinal effects following both acute and chronic oral exposure to fluoride consist of nausea, vomiting, and gastric pain. The irritation of the gastric mucosais attributed to fluoride (as sodium fluoride) forming hydrofluoric acid in the acidic environment of the stomach (Hoffiman et al., 1980; Waldbott, 1981). The uncharged hydrogen fluoride molecule can then penetrate cell membranes and enter the neutral environment of the cytoplasm.

A study by Susheela et al., (1993) assessed the prevalence and severity of gastrointestinal disturbance in area of endemic skeletal and dental fluorosis in India. The highest prevalence (52.4%) of non-ulcerdyspeptic symptoms was found among 288 individuals (69 families) living in a village where the mean fluoride concentration in the 36 separate water sources water was 3.2ppm (range 0.25 to 8.0 ppm). Eleven of these water sources were defined by the authors as safe (i.e., with fluoride levels of 1.0 ppm or less). The authors noted that in patients who reverted to safe water, dyspeptic symptoms and complaints disappeared within 2-3 weeks.

### 2.6.4 Endocrine and Immunological Effects

In the endocrine system where the intermediary metabolism and synthesis of highly sensitive hormones involves enzymatic action, it is expected that interferences with the mechanism by chemical agents would produce early and pronounced clinical effects, hormone chemistry and the possible clinical disturbances of endocrine function, particularly the thyroid gland (Robinson et al., 202). No significant changes in serum triiodothyronine or thyroid stimulating hormone levels were found. Increases in serum epinephrine and norepinephrine levels were also observed. It is unclear if nutritional deficiencies played a contributing role to observed endocrine effects.

A request to the American Academy of Allergy was made by the U.S. public Health Service for an evaluation of suspected allergic reactions to fluoride as used in the fluoridation of community water supplies (Austen et al., 1971). The response to this request included a review of clinical reports and an opinion as to whether these reports constituted valid evidence of a hypersensitivity reaction to fluoride exposure of types I, II, III, or IV (Austen et al., 1971), which are, respectively, anaphylactic or reaginic, cytotoxic, toxic complex, and delayed-type reactivity. The Academy reviewed the wide variety of symptoms presented (vomiting, abdominal pain, headaches, scotomata (blind or partially blind areas in the visual field), personality change, muscular weakness, painful numbness in extremities, joint pain, migraine headaches, dryness in the mouth, oral ulcers, convulsions, mental deterioration, colitis, pelvic hemorrhages, nasal congestion, skin rashes, epigastria distress, and hematemesis) and concluded that none of these symptoms were likely to be immunologically mediated reactions of types I-IV. No studies were located that investigated alterations in immune response following fluoride exposure in humans. In a study with rabbits administered 4.5 mg fluoride/kg/day as sodium fluoride for 18 months, decreased antibody titers were observed (Jain and Susheela, 1987).These results were observed after 6 months of treatment; the authors hypothesized that a threshold level is reached at which time the immune system is impaired. However, as only one dose level (4.5mg fluoride/kg/day) was tested, no dose-effect.

Fluoride has been shown to interfere with glycolysis. Because the central nervous system relies heavily on this energy source, hypotheses have been advanced as to a mechanism for fluoride effects on glycolytic enzymes could explain the neuromuscular symptoms seen frequently in cases of fluoride poisoning (e.g. Tetany, Parenthesis, Paresis, convulsions) studies tend to indicate that hypocalemia caused by fluoride binding of calcium causes these symptoms (Eicher et al., 1982). The decreases in intelligence were reported in children living in areas of China with high levels of fluoride in the drinking water, as compared to matched groups of children living in areas with low levels of fluoride in the drinking water (Li et al., 1995; LU et al; 2000), but these studies are weak inasmuch as they do not address important confounding factors.

### 2.6.5 Reproductive Effects

There are limited data on the potential of fluoride to induce reproductive effects in humans following oral exposure. A meta-analysis found a statistically significant association between decreasing total fertility rate and increasing fluoride levels in municipal drinking water (Freni, 1994). Annual county birth data (obtained from the National Centre for Health Statistics)for over 525,000 women aged 10-49 years living in areas with high fluoride levels in community drinking water were compared to a control population approximately 985,000 women )living in adjacent counties with low fluoride drinking water levels. The fluoride exposed population lived in counties reporting a fluoride level of 3ppm or higher in at least one system. The weighted mean fluoride concentration (county mean fluoride level weighted by the 1980 size of the population served by the water system) was 1.51 ppm (approximately 0.04mg fluoride/ kg/day), and 10.40% of the population was served by water systems with at least 3 ppm fluoride.

Fluoride crosses the placenta in limited amounts and is found in fetal and placental tissue (Gedalia et al., 1961; Theuer et al., 1971). The available human data suggest that fluoride has the potential to be developmentally toxic at doses associated with moderate to severe fluorosis. The human and animal data suggest that the developing fetus is not a sensitive target of fluoride toxicity. Analysis of birth certificates and hospital records for over 20,000 babies born in an area with fluoridated water and over 1,000,000 babies born in a low fluoride area found no difference in the incidence of birth defects attributable to fluoride (Erickson et al., 1976). Exposure to high levels of fluoride has been described together with an increased incidence of Spina Bifida (Gupta et al., 1995). The occurrence of spina bifida was examined in a group of 50 children aged 5-12 years living in area of India with high levels of fluoride in the drinking water (4.5-8.5 ppm) and manifesting either clinical (bone and joint pain, stiffness, and rigidity), dental, or skeletal fluorosis. An age and weight-matched group of children living in areas with lower fluoride levels (1.5 ppm) a control group. Spina bifida was found in 22 (44%) of the children in the high fluoride area and in six (12%) children in the control group. This study did not examine the possible role of potentially important nutrients such as folic acid, however, and had other study design flaws.

The acceleration of the aging process by fluoride occurs at the bio-chemical level through enzyme inhabitation, collagen break down, genetic damage or disruption of the immune system. Fluoride damage enzyme, and results in a wide range of chronic disease. Fluoride as low as 1 mg/1 causes breakdown of collagen, the most abundant of the body protein at 30%. It leads to irregular formation of collagen, which serves as a major structural component of skin, ligaments, tendons, muscles, cartilage, bone and teeth. A number of studies revealed that fluoride causes genetic damage. The mechanism cannot be exactly pinpointed because fluoride interferes with a number of physiological processes. Most evidence indicates that it Acts on the DNA Repair Enzyme system. It may also interfere with DNA synthesis. If the unprepared DNA damages occur in a cell, producing a sperm or egg it will be replicated in every cell of the offspring body and leads to birth defects. Irreparable damage of a segment of DNA is responsible for control of cell growth and may cause turners or cancer.

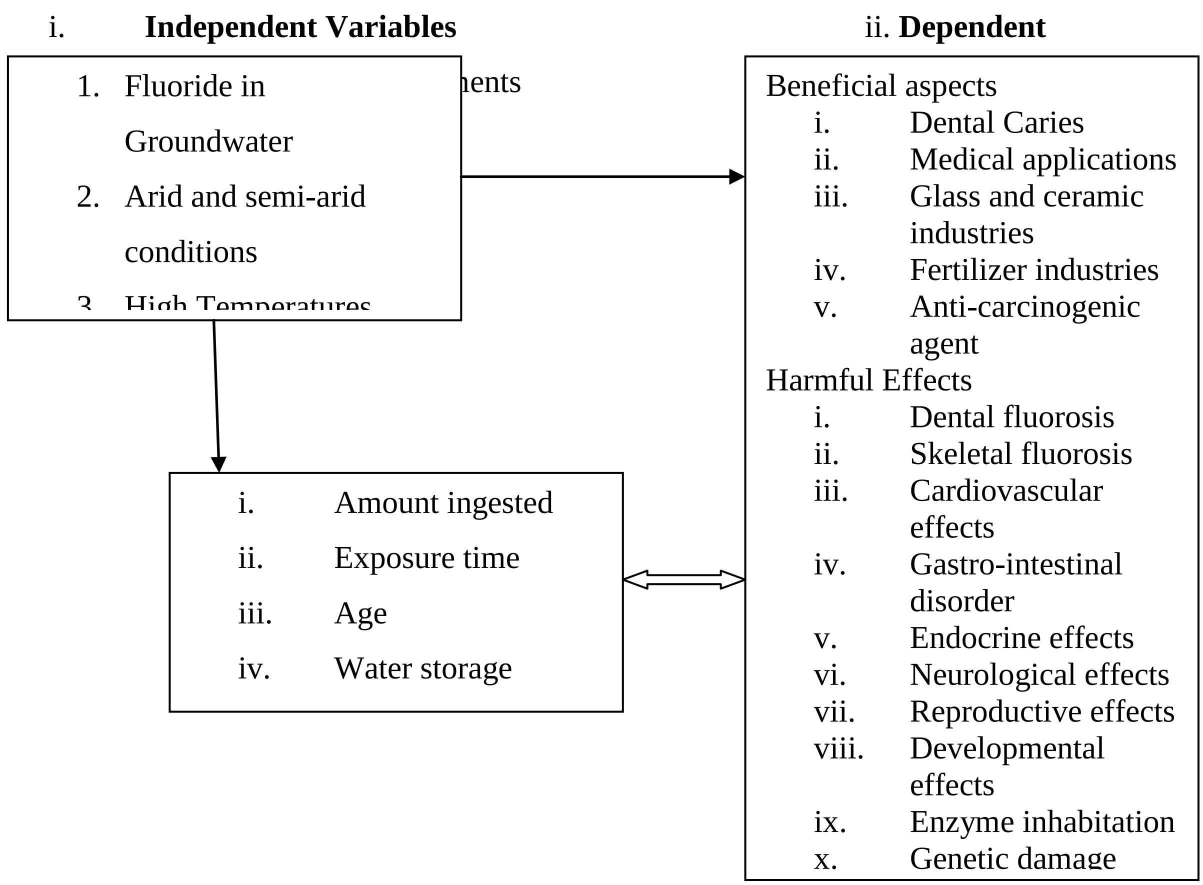
Fluoride interacts with the bonds of protein molecular required to maintain the normal shape of proteins. The fluoride effect the immune system by i) Damage the immune system by inhibiting the migration rate of white blood cells to infected means, ii) Interferes with phagocytosis (destruction of bacteria and other foreign agents by white blood cells or iii) Induces the release of super oxide free radicals in resting white blood cell, the fluoride induced interference leads to an increased and more prolonged exposure of the body to foreign materials and releases free radicals damaging the body.

### 2.6.6 Fluoride as Carcinogen

Fluoride was found to be an equivocal carcinogen by the National cancer institute. Toxicological effects due to excess of fluoride is 6.9 fold and cause bone cancer in young males. Several epidemiological studies are available on the possible association between fluoride in drinking water and cancer rates among the population IACR evaluated these studies on fluoride and carcinogenicity in humans. (IARC, 1987; Maurer et al., 1990). Numerous epidemiological studies have examined the issue of a connection between fluoridated water and cancer. The weight of evidence indicates that no such connection exists. However, all of the investigations were ecologic studies, and the sensitivity limit of even the most sensitivity analysis in these studies appears to be a 10-20% increase. Since any carcinogenic effect of fluoride at the levels found in water supplies would probably be below this level of sensitivity, a National Toxicology Program (NTP) cancer bioassay was conducted to assess the effect of fluoride on cancer incidence in animals (Bucher et al., 1991; NTP report, 1990). The NTP study found equivocal evidence of a fluoride-related increase in osteo-sarcomas in male rats, and no evidence of any fluoride-related neoplasm in female rats or male or female mice. A study sponsored by Proctor and Gamble (Maurer et al., 1990) found no evidence of fluoride carcinogenicity in either male or female rats. Both studies contain limitations that preclude strong conclusions. The NTP is presently carrying out additional experiments on the relationship, if any, between fluoride and cancer. The International Agency for Research on cancer (IARC) reviewed the literature on fluoride carcinogenicity in 1982. It concluded that there is no evidence from epidemiological studies of an association between fluoride ingestion and human cancer mortality, and the available data are inadequate for an evaluation of the carcinogenicity of sodium fluoride in experimental animals (IARC, 1982). Several major cancer bioassays of fluoride have been conducted since the IARC review.

## 2.7 Conceptual Framework

The relationship between the independent and dependent variables on consumption of ground water with high fluoride are presented in the conceptual framework below.




## 2.8 Conclusions

The conclusion from this review is weathering and other breakdown of alkaline volcanic rocks and associated products, together with a minor direct input from volcanic emanations, account for the generally high fluoride content of the natural waters of Kenya. This is especially so in the Rift Valley region, where the trend with regard to fluoride concentration is lake water having the highest concentration followed by groundwater and springs and river water having the lowest concentration. The alkaline saline lakes have usually high fluoride values, which are attributed in the main to evaporate concentration. River water in some areas is found to have less than the recommended level of fluoride (1.3 ppm), a situation expressed in the high frequency of dental caries. In this case, increased fluoride intake is desirable, and can be achieved by controlled direct additions to drinking water or to specific foods. Adding fluorides to soil that produce food crops is ineffective because fluoride in the soil are inactivated and do not usually find their way in to the food chain.

Due to weathering of rocks the Ca-Mg/carbonate concentration which form in arid and semi-arid areas appears to be good sink for the fluoride ion (Jack et al., 1980). The factors that control the leachability to fluoride from carbonate concentration or from the topsoil horizon may be (1) PH of the draining solution (2) Alkalinity (3) The dissolved carbon (IV) oxide in water and in features in the soil. If the groundwater is more alkaline and stagnant for longer time, all the fluoride minerals in a basic rocks, and overlying soil that are rich in mafic minerals undergoes ionization facilitating the ground water to get enriched with fluoride.

Borehole waters, on account of their generally higher fluoride content may require defluoridation, for which a number of simple and readily applicable techniques are now available (Nawlakhe and Bulusu, 1989); this will help reduce the number of cases of fluorosis in areas largely dependent on borehole water for drinking.

# CHAPTER THREE

## 3.0 METHODOLOGY

### 3.1 Introduction

This chapter is subdivided into the following subtopics: research design, location of study, population of study, sampling procedures, data collection tools, data analysis and ethical considerations.

### 3.2 Study Area

Makindu District is located in Makueni County of the Eastern region of Kenya. It is found 70 kilometers to the South of Wote town, the Makueni County headquarters. The district is transversed by the railway line that runs from Mombasa to Kampala City in Uganda. It is also transversed by the Mombasa-Nairobi highway and it is about 313 Kilometers from Mombasa City and 170 kilometers from Nairobi, the capital city of Kenya.

Makindu District is located between 2°16' 30.00"S, 37°49' 12.00"E (Fig 3.1) and has an approximate area of 8008.9 square kilometers and an estimated population of about 121,934. Administratively, Makindu District has one division, which is divided into four locations namely; Makindu, Nguumo, Kiboko and Twaandu.

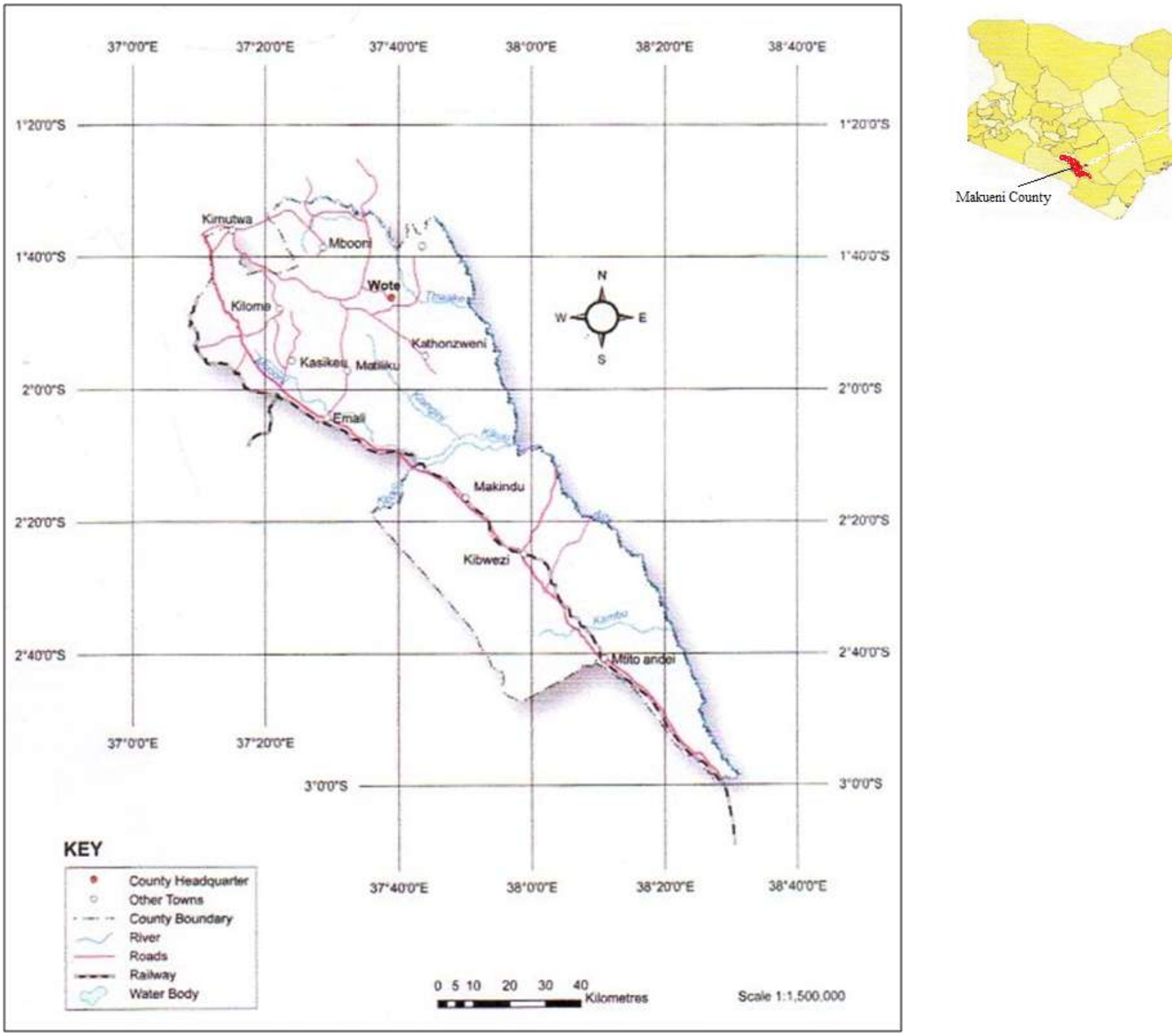



**Fig. 3.1** Map of Makueni County Showing the Nine Districts incliding Makindu District (Foundation Atlas).

Makindu District is bordered by; Kathonzweni District to the North and Kibwezi District to the East.

### 3.2.1 Climate

The climate of the area is characterized by a bimudal low rainfall regime that falls mainly in the periods of February to April and October to December, at the change of the monsoon. The first rainy season is from mid-March to end of April whilst the second starts from late October to late December. The dry season is experienced between early May to mid-October. The mean annual rainfall amounts to approximately 600mm. The mean annual potential evaporation amounts to about 2300mm.The actual evaporation is of course lower. The annual mean temperature is about 27°C while the annual mean minimum temperature is about 16°C (Meteorological Department, Makindu).

### 3.2.2 Vegetation and Land-use

The area falls within the arid and semi-arid ecological zone. Due to its low rainfall and poor soils in some areas the vegetation is also low. Trees mostly found in the area are acacia, baobab, euphorbia and thorny shrubs. Cultivation is low but during the wet season vegetation is lush and food crops such as green grams, cowpeas and tubers such as cassava are grown. Livestock such as goats, sheep and cows are kept by the community. The impact of human activity is indiscriminate tree felling for charcoal burning is having a toll on the vegetations.

### 3.2.3 Physiography and Hydrology

Both perennial and ephemeral surface water sources are important elements in water supply in the study area as competition for water by the desperate interests intensifies. The topography is marked by rumples of small upland and a lowland area. Generally mean elevation in the area is about 1000m above sea level. The area has an undulating terrain from Northwest to Southeast. Several streams drain in the area that is strictly ephemeral in nature. The major river is Kiumbi which is seasonal with many wells dug along its length.

### 3.2.4 Geology

The geology of the area is described by Saggerson (1963). In general, the geology is characterized by two major geological and lithological systems, the Precambrian Basement system and the Younger Tertiary basaltic lavas. The Basement System rocks in the Simba-Kibwezi area are mainly gneisses, schist, granulite and crystalline limestone of sedimentary origin. Two series can be recognized; the Kasagau and Kuruse series, and these occupy approximately half of the area. The Kuruse series is characterized by dolomitic limestones that form conspicuous features in the southwest part of the area. To the north of the railway, the rocks of the Kasigau series contain high grade index mineral sillimanite, which frequently occurs in the garnetiferous and muscovite-rich rocks interbanded with graphite gneisses. These rocks are poorly exposed and form the few scattered outcrops in the principal river-courses where a fairly continuous section can be recognized. After their deposition, the Achaean rocks were highly folded and faulted and subsequently granitized but evidence of migmatization is rare (Saggerson, 1963).

### 3.2.5 Population

The 2009 population and housing census estimated the population of Makindu District as 121,984 (Table 3.1).

**Table 3.1:** The Makindu District population as per locations (Census, 2009)

| **Location** | **Total Population** |
|---|---|
| Makindu | 48,000 |
| Nguumo | 44,000 |
| Twaandu | 11,000 |
| Kiboko | 18,984 |
| Total | 121,984 |

The district has a surface area of 8008.9 $Km^2$ and a population density was recorded as 0.067 persons per sq. Kilometer in the 2009 Kenya population and housing census. The district is sparsely populated due to arid and semi-arid climate. Due to its low rainfall and poor soils in most areas, the land is less cultivated but though they keep livestock such as goats, sheep and cows, their performance is below average. This has led the community to look for alternative means of livelihoods and this has caused indiscriminate tree felling for charcoal burning and wood fuel leading to massive destruction of the natural environment.

### 3.2.6 Health

There are government and private medical facilities located within the district. There is one Sub-county government hospital-The Makindu Sub-County Hospital and three health centres. There are two major private hospitals: The Sikh Temple hospital, and the Makindu Nursing Home. There are about eighteen private clinics. The residents living in the district get their dental health problems addressed at government hospital – The Makindu Sub-County Hospital on week days and in the Sikh Temple Hospital fort-nighty. The residents living in the district visit the dental clinics for problems such as tooth decay (dental caries) and for masking in ‘treatment ‘of dental fluorosis. The district hospital has recorded many cases of fractures emanating from skeletal fluorosis complications (Dr. Andrew Kieti of Makindu sub-County Hospital and Dr. Irungu of Sikh Temple hospital; Personal Communication).

### 3.2.7 Water and Sanitation

Water is essential in the life of man as it is an essential component used to maintain good personal hygiene. Water is supplied to residents by Makindu water and sewerage company (MAWASCO). The water comes from natural fresh water spring origination from Chyulu hills and Mt. Kilimanjaro. However, this fresh water passes through rocks which contain high fluoride hence is contaminated with chemicals (MAWASCO, Makindu). The high concentrations of fluoride (in excess of the W.H.O guideline value of 1.5ppm) are common throughout the Makindu area, and may and do cause adverse health effects in infants (mottling of teeth, skeletal fluorosis) (Gitonga and Nair, 1982). The spring opens in an open concrete tank where the water is chlorinated and then pumped to Makindu town and its environs. The residents who have no access of the piped MAWASCO water get it from wells dug along the main River Kiumbi next to Makindu town. There are also individual wells drilled at people's homes and these also supplement the MAWASCO water. However, the borehole water contains very high levels of fluoride to the tune of 4-5ppm (Gitonga and Nair, 1982).

### 3.2.8 Economic Activities

Persons living in the district engage in a number of economic activities to earn a living. These include; Agriculture, construction, wholesale, retail trade, hotel and restaurants, transportation, communication, real estate, public administration and education. There is a small scale industry, that is, charcoal producing business that provide employment to many.

## 3.3 Research Design

The study adopted an ex post facto design. This design is defined by Lammers and Badia (2005) as a non- experimental research technic. The design is ideal for this study considering the independent variables in this case cannot be manipulated by the researcher. The manifestations of the independent variables, in this case fluoride in groundwater, arid and semi-arid climatic conditions and high temperatures cannot be changed. The dependent variables are; dental carries, medical applications, essential element, dental fluorosis, skeletal fluorosis, reproductive effects among others are only compared on the independent.

## 3.4 Study Populations

The researcher purposively selected Makindu and Kiboko locations to represent the four locations in the district. This is because Makindu and Nguumo locations are supplied with water from the same source (MAWASCO), which also applies to Kiboko and Twaandu locations. The study targeted 286 individuals from Makindu location and 112 people from kiboko location. A total of 398 individuals were interviewed.

### 3.5 Sampling Procedure

To elicit the data to meet the objectives of the research, individuals from the two locations out of the four in the district were purposively selected. Makindu and Kiboko locations were chosen since their water sources are different. Makindu and Nguumo locations are supplied with water from the same source (MAWASCO) which also applies to Kiboko and Twaandu locations,which get water from Kikuu River. The sampling frame was 66, 984 individuals. The sample size was determined with the formula proposed by (Gay, 2003).

$n= N/(1+N(a)^2)$

Where ‘n’ is the sample size

‘N’ is the total number of individuals

‘a’ is the margin of error estimated at 5% (0.05).

$n=66,984/(1+66984(0.05)^2)$

n=66984/168.46

n=397.625549091

n=398 persons

Simple proportion was used to calculate the number of individuals for each selected location. Makindu location represents 72% of the sampling frame and so 72% of 398 is 286 whereas Kiboko location represents 28% of the sampling frame which is 112 persons. Out of the 398 individuals, there are three key-informants; two dentists and a health officer. Two dentists are from Makindu location, one from Makindu Sub-County

Hospital and the other from the Sikh Temple Hospital. The health officer is from Kiboko Health Centre.

### 3.6 Data Collection Tools

Three main research tools used are a questionnaire for the key-informants (i.e. the health officers), an interview schedule and an observation schedule to record the mottled enamel and its intensity. Cellphones to interview the potential participants or key-informants were also used where necessary

### 3.7 Ethical Consideration

The respondents were briefed on the research and its importance and none was compelled to participate /complete the questionnaire but were allowed to do so at their will. The completed questionnaires were handled with a lot of confidentiality – so that no information about a respondent(s) leaked out.

### 3.8 Data Analysis

Analysis was done to determine the decayed, filled surfaces, missing teeth and mottled enamel. The residential data was also analyzed to co-relate exposure time of the fluoride and the mottled enamel/dental fluorosis. The data was presented in form of charts, graphs and frequency distribution tables.

## CHAPTER FOUR

## 4.0 DATA PRESENTATION, ANALYSIS AND DISCUSSION

### 4.1 Respondents Bio Data.

The researcher first sought to establish the demographic data of the respondents. This data included; respondents age, gender, education level, District of birth, and residential period.

#### 4.1.1 Respondents Age, Gender and Academic Qualification

The frequency and percentages of respondents' age bracket are presented in Table 4.1.

**Table 4.1:** Frequency and percentage proportion of different Age bracket in Makindu and Kiboko Locations

| | **Makindu location** | | **Kiboko location** | |
|---|---|---|---|---|
| **Age bracket** | **Frequency** | **Percentage** | **Frequency** | **Percentage** |
| Less than 10 | 12 | 4.3 | 4 | 3.6 |
| 10 - 14 | 48 | 16.8 | 19 | 17.0 |
| 15 - 19 | 61 | 21.3 | 19 | 17.0 |
| 20 - 24 | 34 | 11.9 | 14 | 12.5 |
| 25 - 29 | 19 | 6.6 | 11 | 9.8 |
| 30 - 34 | 19 | 6.6 | 11 | 9.8 |
| 35 - 39 | 24 | 8.4 | 5 | 4.5 |
| 40 - 44 | 0 | 0.0 | 5 | 4.5 |
| 45 - 49 | 5 | 1.7 | 5 | 4.5 |
| 50 - 54 | 24 | 8.4 | 5 | 4.5 |
| 55 - 59 | 28 | 9.8 | 10 | 8.7 |
| ≥ 60 | 12 | 4.3 | 4 | 3.6 |
| **Total** | **286** | **100** | **112** | **100** |

The respondents aged 15-19 years were 21.3% and 17% for Makindu location and kiboko location respectively. In Kiboko location it was also noted that those aged 10-14 years were also 17%.  The least respondent were those aged 45-49 years (1.7%) for Makindu location while for Kiboko location it was those who were more than 59 years (3.6%). These results shows that there was a good distribution in age from 10 years to more than 59 years hence the researcher was able to gather information from a good representation of many age groups in the society.

The respondents' gender is presented in Table 4.2. It was found that majority of respondents were male with Makindu location having 65% and Kiboko location having 62.5%. The female respondents were 35% for Makindu location while that for Kiboko location was 37.5%. The males were relatively more than the females due to the fact that in the African setting, the males, being the heads of the family, opted to talk/respond to the research questions.

**Table 4.2:** Frequency and percentage of Respondents Gender

| | **Makindu Location** | | **Kiboko Location** | |
|---|---|---|---|---|
| Gender | Frequency | Percentage | Frequency | Percentage |
| Male | 186 | 65.0 | 70 | 62.5 |
| Female | 100 | 35.0 | 42 | 37.5 |
| **Total** | **286** | **100** | **112** | **100** |

The researcher sought to establish the academic qualification of respondents, in order establish their literacy level and the results are presented in Table 4.3. Majority of the respondents from Kiboko Location and from Makindu Location, 59.8% and 50% respectively, had primary Education as their highest level of Education. This was followed by secondary Education, 40 % in Makindu location and 34.8% in Kiboko location. The academic level with least frequencies was the University degree level with 1.6% and 2.7% in Makindu location and Kiboko location respectively. This shows that, all respondents had basic education which could help them give reliable responses.

**Table 4.3:** Educational level of respondents

| | Makindu Location | | Kiboko Location | |
|---|---|---|---|---|
| Academic level | Frequency | Percentage | Frequency | Percentage |
| Primary | 143 | 50.0 | 67 | 59.8 |
| Secondary | 114 | 40.0 | 39 | 34.8 |
| College | 24 | 8.4 | 3 | 2.7 |
| University degree | 5 | 1.6 | 3 | 2.7 |
| **Total** | **286** | **100** | **112** | **100** |

### 4.1.2 District of birth and Period of Stay in the Study Area

Table 4.4 shows the proportion of those who were born in and outside the study areas. In Makindu, majority (66.8%) were born in the district while 33.2% were born in other districts, where as in Kiboko the number of those born within and outside the district was the same (50%). The respondents who were born in other districts resided in the study areas at the time of the research. This show that the respondents were in a better position to give reliable information concerning water sources in the study area.

**Table 4.4:** Respondent's District of birth

| | Makindu location | | Kiboko location | |
|---|---|---|---|---|
| District of birth | Frequency | Percentage | Frequency | Percentage |
| Makindu | 191 | 66.8 | 56 | 50.0 |
| Other | 95 | 33.2 | 56 | 50.0 |
| **Total** | **286** | **100** | **112** | **100** |

The frequency and percentage of respondents who have lived in the study area for different periods are presented in Table 4.5. Majority (65%) of the respondents had stayed in Makindu location for more than 15 years while 47.3% had stayed in Kiboko

Location for the same number of years. It is assumed that this length of stay was good enough to give reliable results for the study.

**Table 4.5:** Respondent's Period of stay in the location

| | Makindu Location | | Kiboko Location | |
|---|---|---|---|---|
| Period of stay in years | Frequency | Percentage | Frequency | Percentage |
| 1- 5 | 29 | 10.1 | 25 | 22.3 |
| 6 - 10 | 19 | 6.6 | 14 | 12.5 |
| 11 - 15 | 52 | 18.2 | 20 | 17.9 |
| $\geq$ 15 | 186 | 65.0 | 53 | 47.3 |
| **Total** | **286** | **100** | **112** | **100** |

### 4.2 Main Sources of Water

The main sources of water in the study area, according to the respondents, are presented in Figure 4.1. Majority, 80% and 68% respectively, of the respondents in Makindu Location and Kiboko Location relied on tap water from the spring. This was followed by those who relied on borehole water, 10% and 21% respectively in Makindu Location and Kiboko Location. The third important source was rain water, accounting for 8% in both locations. The rivers were least sited source of water with 2% and 3% in Makindu and Kiboko Locations respectively.

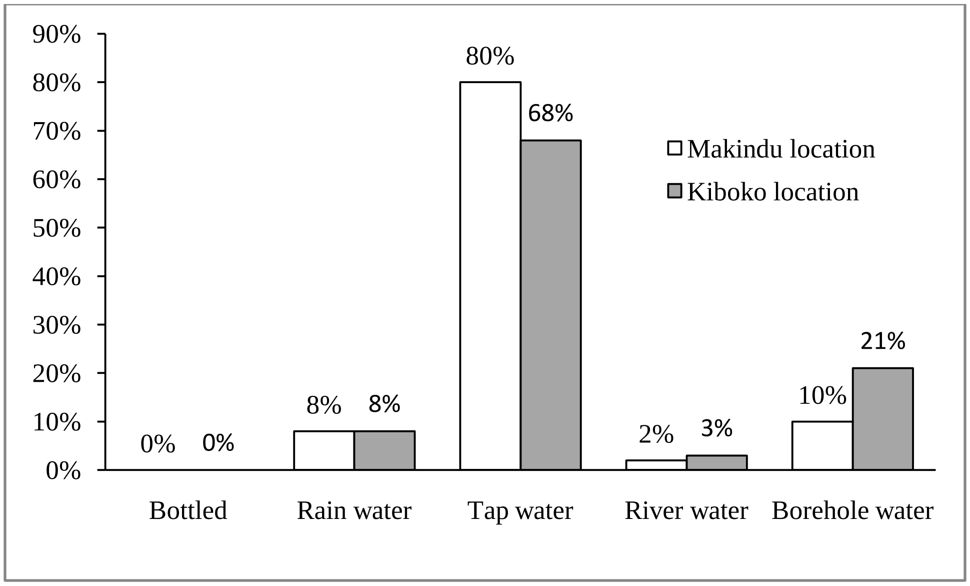



**Figure 4.1:** Percentages of respondents using different water sources in Makindu and Kiboko Locations

### 4.3 Physiochemical Characteristics of Water

The physiochemical characteristics of selected water sources in the study area are presented in Table 4.6. The water quality characteristics varied differently between the three sources, Makindu Spring, Makindu borehole, and Kiboko borehole, with on average Makindu Borehole recording the highest values. In Makindu Borehole chloride, total hardness, total alkalinity, sulfate and magnesium values were above the WHO guidelines. Chloride concentration was lowest in Makindu spring (28 mg/L) whereas total hardness and total alkalinity were highest in Makindu borehole (700 and 851 mg CaCO3/L respectively). Iron concentration was generally low with concentration below detection limit of 0.01 mg/L, except in Makindu borehole (0.07 mg/L). pH values were within the range of WHO guidelines and calcium was lower than WHO guideline value in the three water sources.

**Table 4.6** Chemical characteristics of water from Makindu Spring (Raw) and Makindu Borehole and Kiboko Borehole and the WHO guidelines for drinking water. Bolded values are above WHO guidelines

| Parameter | Makindu Spring (Raw) | Makindu Borehole | Kiboko Borehole | WHO Guidelines |
|---|---|---|---|---|
| Chloride (mg/L) | 28 | **260** | 144 | 250 |
| Total Hardness (mg CaCO3/L) | 260 | **700** | 260 | 500 |
| Total Alkalinity (mg CaCO3/L) | 408 | **851** | 348 | 500 |
| pH | 8.53 | 7.3 | 8.17 | 6.5-8.5 |
| Sulphate (mg/L) | 57.1 | **622** | 50 | 450 |
| Iron (mg/L) | <0.01 | 0.07 | <0.01 | 0.3 |
| Calcium (mg/L) | 48 | 70.8 | 6 | 100 |
| Magnesium (mg/L) | 34 | **122.4** | 2.7 | 100 |
| Sodium (mg/L) | 110.5 | 193 | **272** | 200 |
| Potassium (mg/L) | 12 | | 0.4 | |

The fluoride concentration in water from different sources is presented in Figure 4.2. All the three boreholes covered during the study had fluoride concentration above the WHO maximum allowable value of 1.5 mg/L. Kiboko Borehole had the highest concentration of 4.2 mg/L followed by Makindu Boys Borehole with concentration of 2.85 mg/L. Kalii Borehole had the lowest fluoride concentration (1.62 mg/L) among the three borehole covered during the study. Raw water from Makindu Spring, the main source of drinking water for Makindu Town, had fluoride concentration of 1.1 mg/L, which is well below the WHO maximum allowable value.

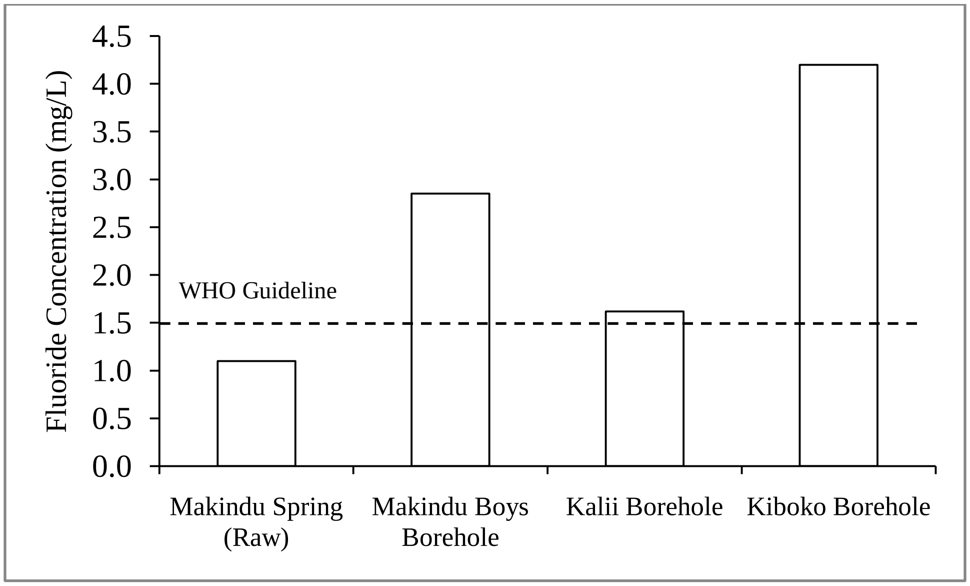



**Figure 4.2** Fluoride Concentration in water from different water sources within the study area.

The high fluoride concentration in groundwater indicate the population that use boreholes as a water source (10-20%, Figure 4.1) are exposed to health risks associate with high fluoride. According WHO (1984) there is wide variation in fluoride levels in the natural waters in Kenya, with concentrations above and below the optimal range set by the world Health organization for drinking water. However, river waters generally have fluoride contents in the lower part of this range whereas ground waters show much higher levels (Bakshi, 1974; Njenga, 1982). Thus the exposure to fluoride in Makindu District is likely to be more severe to the population that uses water from groundwater sources.

### 4.4 Impact of Fluoride in Drinking Water to Human Population

The third objective of this study was to determine the impact of fluoride in drinking water to human population in Makindu District. To achieve this objective the respondents were requested to indicate their condition of teeth. The results of responses are presented in Figure 4.3.

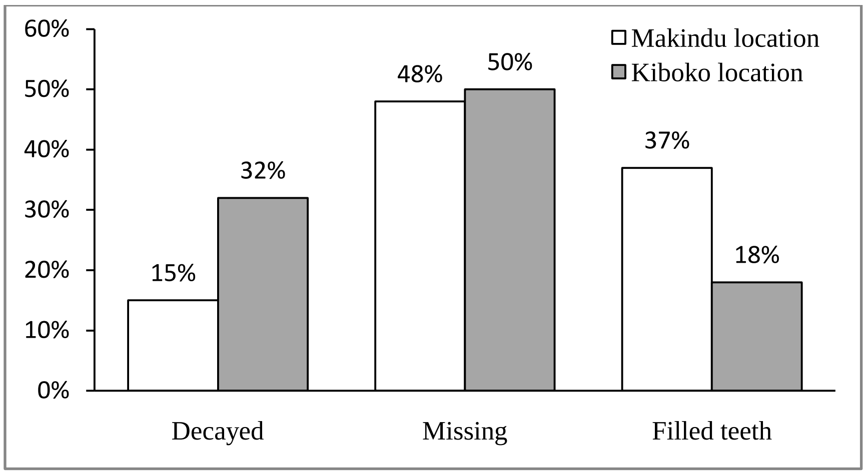



**Figure 4.3:** Percentages of respondents with different teeth conditions in Makindu and Kiboko Locations

Majority of the respondents from Kiboko Location and Makindu Location had missing teeth (50% and 48% respectively). The percentage of respondents with decayed teeth were 15 and 32 and the percentage of those with filled teeth was 37 and 18 respectively in Makindu Location and Kiboko Location.  There are several factors that may cause the three teeth condition in humans including sugar rich diet, accidents, hereditary and level of teeth care among others but consumtion of high fluororide water may also cause or exacerbate the occurrence of some the condition.  Excess level of fluoride would course dental fluorosis which is a condition that results from the intake of excess levels of fluoride during the period of tooth development, usually from birth to approximately 6-8 years of age.  It has been termed as hypoplasia or hypomineralization of dental enamel and dentine and is associated with the excessive incorporation of fluoride into these structures. The dental enamel are both post eruptive phenomena (i.e, acquired after tooth eruption and occur as a consequence of the enamel hypomineralization) (Richards et al., 1986).

The study sought to establish the intensity of mottled teeth among the respondents and the responses are presented in Table 4.7. Most of the respondents from Kiboko Location and from Makindu Location, (38.4% and 33.3% respectively) had moderately to severely mottled enamel. These results show the impact of fluoride in water. The results agrees with Dean (1942) who argued that the severity of mottled enamel condition is generally characterized as ranging from very mild to severe, is related to the extent of fluoride exposure during the period of tooth development. Mild dental fluorosis is usually typified by the appearance of small white areas in the enamel; individuals with severe dental fluorosis have teeth that are stained and pitted ("mottled") in appearance. In human fluorotic teeth, the most prominent feature is a hypomineralization of the enamel. The results also agree with Elvove (1937) who argued that dental fluorosis is caused in human being consuming water containing 1.5mg/1 or more fluoride, particularly from birth to the age of eight. Mottled enamel usually takes the shape of modification to produce yellow brown stains or an unnatural opaque chalky white appearance with occasional striations patting. The incidence and severity of mottling was found to increase with increasing concentration of fluoride in drinking water.

**Table 4.7:** Frequency and percentage of different levels of mottled enamel among the study respondents

| | **Makindu location** | | **Kiboko location** | |
|---|---|---|---|---|
| Intensity | Frequency | Percentage | Frequency | Percentage |
| Very mild | 5 | 1.7 | 6 | 5.3 |
| Mild | 43 | 15.0 | 20 | 17.9 |
| Moderately | 95 | 33.3 | 43 | 38.4 |
| Moderately severe | 57 | 19.9 | 17 | 15.2 |
| Severe | 33 | 11.5 | 6 | 5.3 |
| **Total** | **286** | **100** | **112** | **100** |

Comparison between the two locations show a difference in the intensity level of mottled teeth. Makindu Location had relatively high number of respondents with moderately severe to severe mottled teeth (31%) compared to Kiboko Location (20.1%). In contrast, Kiboko Location had relatively higher number of respondents with very mild to mild mottled teeth (23%) and compared to Makindu Location (16.7%). This difference maybe as a result of difference in fluoride concentration levels in water sources in the two locations.

### 4.5 Mitigation Measures Against the Ill-effects of Fluoride in Ground Water

The last objective for this study was to determine the possible mitigation measures against the ill effects of fluoride in ground water. The researcher sought to establish the frequency of teeth brushing by the respondents and the results were presented in Table 4.8.

**Table 4.8:** Percentages of frequency of Tooth brushing in a day by the respondents

| | **Makindu location** | | **Kiboko location** | |
|---|---|---|---|---|
| Frequency | Frequency | Percentage | Frequency | Percentage |
| < 2times per day | 176 | 61.5 | 62 | 55.4 |
| ≥ 2 times per day | 110 | 38.5 | 50 | 44.6 |
| **Total** | **286** | **100** | **112** | **100** |

It was observed that 61% and 55.4% of the respondents from Makindu Location and Kiboko Location respectively, brushed their teeth about twice per day and those brushing more than two times in a day were respectively 38.5 and 44.6%. This shows that the respondents were serious in taking care of their teeth.

The researcher further sought to establish the type of tooth paste used in Makindu district and the responses are presented in Figure 4.4.

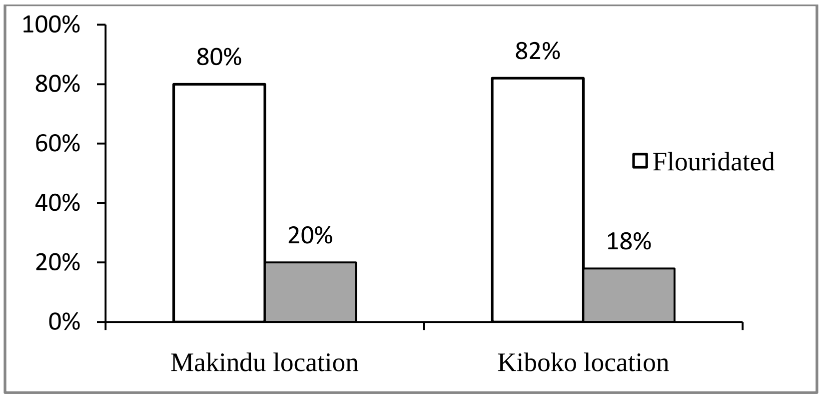



**Figure 4.4:** Percentage of respondents using fluoridated and non-fluoridated toothpaste in the study area

It was found out that majority of the respondents from Makindu Location and Kiboko Location (80% and 82% respectively) use fluoridated tooth paste to clean their teeth. This seems to be a mitigation strategy applied by Makindu District residents against the ill effects of fluoride in ground water. These results are in line with Fleischer et al, (1974) who argued that fluoride has a significant mitigating effect against dental caries if the concentration is approximately 1.0mg/L). However, given that the water in this area has high fluoride the use of fluoridated toopaste should be deemphasized since it does serve the purpose of enhancing dental health especially given that exposure of higher concentrations of fluoride can cause dental fluorosis.

**Table 4.9:** Visit to dental clinics

| | Makindu Location | | Kiboko Location | |
|---|---|---|---|---|
| Reason | Frequency | Percentage | Frequency | Percentage |
| Check up | 26 | 9.1 | 19 | 17.0 |
| Dental problem | 147 | 51.4 | 61 | 54.5 |
| None | 113 | 39.5 | 32 | 28.5 |
| **Total** | **286** | **100** | **112** | **100** |

Table 4.9 shows the frequency of visit to dental clinics in the past year for different reasons and those who never visited. Majority of the respondents had visited from Kiboko location and Makindu Location (71.5% and 60.5% respectively) had visited dental clinic with dental problems or for checkup. This shows that the residents were conscious of the need for dental care and also that dental services were available in the area.

### 4.6 Hypothesis of the Research

The hypothesis of this study is that the groundwater fluoride may be higher than the recommended World Health Organization upper limit of 1.5mgli hence leading to ill-effects on human population in Makindu District. This hypothesis was tested using Chi-Square test. This test was necessary because it tests association and statistical dependence. By this test the researcher was able to establish whether there was a significant association between the ground water fluoride in Makindu District and ill – effect on human population. The Chi-square results were presented in Table 4.10.

These results imply that there is an association between the ground water fluoride in Makindu District and ill – effect on human population since all the P-values are less than 0.05 at 95% confidence level. The results therefore imply that, each of the independent variable namely; exposure, extent, impact and mitigation is statistically associated with ill-effect on human population.

**Table 4.10:** Chi-Square test values to establish the association between ground water fluoride and ill-effects on human population in Makindu District

| | Value | df | Asymp. Sig. (2-ided) |
|---|---|---|---|
| Pearson Chi-Square | 14.0[a] | 4 | .007 |
| Likelihood Ratio | 7.21 | 4 | .025 |
| Linear-by-Linear Association | 4.21 | 1 | .040 |
| N of Valid Cases | 398 | | |

a. 10 cells (100.0%) have expected count less than 5. The minimum expected count is .07.

# CHAPTER FIVE

## 5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Summary of the Findings

The study established that majority (80% and 68%) of the respondents from Makindu Location and Kiboko Location respectively relied on tap water from the spring. This was followed by 10% and 21% from Makindu Location and Kiboko Location respectively who relied on borehole water and 8% rain water. This exposed the human population to fluoride contained in groundwater.

On comparison on water chemical from spring water and borehole water, it was established that the borehole water had more sodium 272 mg/l compare to the spring water (110.5 mg/l). Also the springs water had very high total hardness (260mg $CaCO_3$/L) compared to borehole water (26mg $CaCO_3$/L. The springs water had high total alkalinity (408mg $CaCO_3$/L) compared to borehole water (348mg $CaCO_3$/L). However the borehole water had very high chloride (144mg/L) compared to spring water (28mg/L). Finally borehole water had more total dissolved solids (767mg/L) compared to spring water (641.7mg/L). All the other chemicals are almost the same in amounts.

On the impact of fluoride, the study revealed that majority of the respondents (50% and 48%) of the respondents from Kiboko Location and Makindu Location respectively had missing teeth. Also most (38.4%) of the respondents from Kiboko location and 33.3% from Makindu location had moderate mottled enamel. This is an indication that the people in Makindu District were taking water containing fluoride which caused dental fluorosis.

To mitigate this situation the study revealed that 61.5% and 55.4% of the respondents from Makindu Location and Kiboko Location respectively brushed their teeth less than twice per day. This shows that the respondents were serious in taking care of their teeth. Also majority (80% and 82%) of the respondents from Makindu Location and Kiboko Location respectively used fluoridated tooth paste to clean their teeth. This is a mitigation strategy applied by Makindu District residents against the ill effects of fluoride in ground water. It was also revealed majority (54.5% and 51.4%) of the respondents from Kiboko Location and Makindu location respectively had visited dental clinic with dental problems. This shows that the residents were visiting dental clinics as a mitigation strategy for their dental problems which included dental checkup, tooth extraction and tooth filling.

## 5.2 Conclusions From the Study

Based on the findings of this study it can be concluded that the water source for Makindu District population which is mainly tap water from the spring and borehole water exposed them to fluoride. This is because of high fluoride concentration in groundwater, well above the WHO maximum allowable levels of 1.5 mg/L

It was observed that the Makindu District population had stained/mottled enamel teeth which resulted from the intake of excess levels of fluoride during the period of tooth development.

The study also found out that for the respondents to mitigate the dental problem they used tooth paste which was fluoridated as well as attending dental clinics in case of dental problem.

## 5.3 Recommendations From the Study

Based on the findings of this study the researcher made the following recommendations:

i. The ministry of water and the County Government should introduce de-fluoridation systems to remove fluoride from water being supplied to the community. This would in the long run reduce the effect of fluoride on teeth.
ii. Public awareness initiatives on the effect of consumption of high fluoride water should be initiated by the County Government and other stakeholders
iii. Alternative sources of water should be developed for the population depending on the boreholes with high fluoride water.
iv.

### 5.4 Suggested Recommendations for Further Research

This study investigated the exposure to fluoride in groundwater and its impact on human health to the population in Makindu District, Makueni County. Further research can be done on the following:

i. Study on and documentation of the water quality status of all the water sources in Makindu District.
ii. Study of alternative water treatment methods using locally available material including herbs.
iii. More detailed study on the health effects associated with consuming high fluoride water among the community.

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# APPENDICES

## APPENDIX 1: QUESTIONNAIRE

SOUTH EASTERN KENYA UNIVERSITY (SEKU)

SCHOOL OF ENVIROMENT AND NATURAL REASOUSESMANAGEMENT

ASSESMENT OF THE IMPACTS OF GROUNDWATER FLUORIDE ON HUMAN HEALTH IN MAKINDU DISTRICT MAKUENI COUNTY

The information collected from this survey is strictly confidential and is to be used for Academic purposes only.

**Informed consent form**

A research is being undertaken to asses the fluoride onted in Groundwater and its impact on human health in Makindu District Makueni County by a student from south Eastern Kenya university .You have been identified as a key-info formant in this research and therefore a respondent to a few questions .The information You provide will be treated with confidentiality and will be used for academic purposes only.

## APPENDIX A: Interview Schedule

**Informed Consent Form**

A research is being undertaken to study the impact of fluoride in groundwater in Makindu District, Makueni County by a student from South Eastern Kenya University. You have been identified as a key stakeholder in this research and therefore a respondent to a few questions. The information you provide will be treated with confidentiality and will be used for academic purposes only.

**Module A: Household Identification**

| | | | |
|---|---|---|---|
| A1. Date of interview | Day | Month | Year |
| A2. Location Name | | | |
| A3. Name and Gender of Chief | Name | | Gender |
| A4. Name and Gender of Household Head | Name | | Gender |
| A5. Name of Respondent/Relation with household head | Name | Relation | Gender |

**Module B: Respondent's General Information**

B1. What is your age (in year)?

a) 10 – 14

b) 15 – 19

c) 20 – 24

d) 25 – 29

e) 30 – 34

f) 35 – 39

g) 40 – 44

h) 45 – 49

i) 50 – 54

j) 55 – 59

k) ≥ 60

B2. What is your Level of Education?

a) Primary

b) Secondary

c) Tertiary

d) University

B3. What is your occupation?

……………………………………………………………………………………..

B4. Which is your district of birth?

a) Makindu

b) B) Other (specify)

B5. Residential period in Makindu District (in years) ___________________________

**Module C: What is your main source of drinking water?**

a) Bottled water

b) Rain water

c) Tap water

d) River water

e) Borehole water

C2. What is your main method of water storage?

a) Closed tanks

b) Open tanks

c) Jerrcans

d) Other (specify)……………………………………..

**Module D: Personal Dental Health Information**

D1. Do you use toothpaste?

a) Yes

b) No

D2. If ‘Yes’ what type of toothpaste do you use?

a) Fluoridated

b) Unfluoridated

D3. If fluoridated how often do you brush your teeth?

a) $<$ 2 times/day

b) $\geq$ 2 times/day

D4. Do you visit dental clinics?

a) Yes

b) No

D5. If yes, what for?

a) Check-ups

b) Dental problem

D6. Do you have any decayed, missing or filled teeth (DMFT)

a) Yes

b) No

**Observation Checklist**

1. Does the respondent have stained/mottled enamel?

a) Yes

b) No

2. If mottled, what is the intensity?

a) Very mild (small, opaque paper-white area seen)

b) Mild (white opaque area at least half of the tooth surface and faint brown stains)

c) Moderately (brown stain frequently seen)

d) Moderately severe (brown stains present and of greater intensity)

Severe (deep brown to black enamel)

**QUESTIONNAIRE FOR THE KEY INFORMANTS**

**Module A: Key- Informant Identification**

A1. Date of interview

A2. Name of hospital/health family

A3: Name and gender of the health officer

A3. Position in the hospital

| | | |
|---|---|---|
| Day | month | year |
| Name | | |
| Name | gender | |
| Position | | |

**Module B. Health Record Information**

B1. How often do you offer dental clinic services?

a)Daily

b) Weekly

c)|Fortnightly

d) Monthly

e) Other (specify)

B2.For what purpose do the patient visits the clinics?

a)check-ups

b) Dental problems

B3.If dental problem , what is the main issue?

a)Decayed teeth

b) Molted enamel

B4.How many patients have had there tooth /teeth extracted during this last thirty days?________________________-

B5.What was the main reason for the tooth/ teeth extraction ?____________________________

B6. How many patients have had this teeth swiftest filled during the last thirty days?___________________________

B7.What is the frequency of molted /stained enamel in the patient who visited the clinic in the last thirty days?______________________________________________

B8What services do you offer to patients with meltted enamel (i.e. stained teeth)

**Module C. Recommendations**

C1.What is your general comment on the state of dental health in Makindu District?___________________________________________________________________

____________

C2.What are your recommendations as a health officer/specialist on dental health in Makindu

District?__________________________________________________________________________