THE RELATIONSHIP OF DENTAL FLUOROSIS, INTELLECTUAL EFFICIENCY AND WORKING MEMORY IN 13-15-YEAR-OLDS LIVING IN LOW, MEDIUM AND HIGH-WATER FLUORIDE AREAS IN KAJIADO COUNTY

V60/82954/2015: INDUSWE BENJAMIN (BDS, UoN)

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT FOR THE AWARD OF A MASTERS DEGREE IN PAEDIATRIC DENTISTRY, UNIVERSITY OF NAIROBI

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DECLARATION

I declare that this is my original and it has not been submitted for a degree award to any University.

Signed…………………………………..……………………. Date…………………….………..

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DEDICATION

I dedicate this dissertation to the late Dr Joel Namunguba Mbute (RIP), the gentle giant.

May the Almighty continue to protect your young family?

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LIST OF ABBREVIATIONS

BDS	-	Bachelor of Dental Surgery
Mg/l	-	milligrams per litre
KNBS	-	Kenya National Bureau of Statistics
IE	-	Intellectual Efficiency
IQ	-	Intelligence Quotient
TFI	-	Thylstrup and Fejerskov Index
Mg/kg/day	-	milligrams per kilogram per day
Ppm	-	parts per million
WHO	-	World Health Organization
ANOVA	-	Analysis of Variance
CNS	-	Central nervous system
Mm	-	millimolar
NaF	-	sodium fluoride
DNA	-	Deoxyribonucleic acid
RNA	-	Ribonucleic acid
AWM	-	Auditory working memory
WM	-	Working memory
UoN	-	University of Nairobi

DEFINITION OF TERMS

Dental fluorosis- WHO defines dental fluorosis as the hypomineralisation of tooth enamel caused by ingestion of excessive fluoride during enamel formation which appears as a range of visual changes in enamel causing different degrees of intrinsic tooth discolouration. The severity depends on the dose of fluoride, duration of intake and the age of the individual at the time of exposure.

Memory- the faculty by which the mind stores and remembers information. (Oxford dictionary).

Sensory memory- defined as that part of the memory system which is the initial contact of the stimulant and is only capable of retaining information or a brief period. Atkinson-Shiffrin.

Working memory-defined as that part of memory that keeps information temporarily and processes it at the same time. Also called short term memory. It's like doing a mathematics problem in which you store the numbers temporarily and handle it at the same time. Atkinson-Shiffrin

Episodic memory- defined as the type of memory in which the memories of the personal experience are stored and are associated with particular places and times over a long period. Atkinson-Shiffrin

Intellectual efficiency- Psychological inventory defines it as a measure of the extent to which a person makes efficient use of the intelligence he or she has. It's also called a non-intellectual intelligence test. It's a scale that was used to measure personality traits that coincided with a high level of intellectual ability.

ABSTRACT

Introduction: WHO recommends that water fluoride does not exceed 1.5mg/l. Intake of higher concentration has been reported to cause dental fluorosis, skeletal fluorosis and also to be a neurotoxin. Water is the primary source of fluoride to the human body.

Study aim: The study aimed to determine the fluoride concentration in water, the prevalence and severity of dental fluorosis; the intellectual efficiency and working memory of children born and living in different fluoride areas and their differences and associations if any.

Materials and methods:

Study area and design: A cross-sectional descriptive study design was conducted in Kajiado county Kajiado North subcounty. The study was done between October 2016 and March 2017. A pilot study was done to determine the fluoride content of the water in selected areas in Kajiado North sub-county.

Sampling and sample size: Seven schools were randomly selected according to fluoride content in the area of water. Two hundred and sixty-nine participants, 13-15-year-old adolescents who attended day public schools, were chosen from the three areas of high fluoride, medium fluoride and low fluoride. The areas were then divided into three of low with water fluoride ≤1.0 mg/l; medium with water fluoride ≥1.1 mg/l and ≤2.0mg/l and high fluoride with water fluoride ≥2.1mg/l none had significant heavy metal content. The fluoride in water was analysed using the specific fluoride ion-selective electrode. The use of a semistructured questionnaire collected socio-demographic data while the Thylstrup and Fejerskov index used to determine the degree of dental fluorosis.

The working memory test was done using the Weschler Intelligence Scale for Children V and the intelligence efficiency done using Wide Range Achievement Test-IV.

The SPSS version 22.0 was used for data analysis and the study was conducted subject to consent from the University's Research and Ethics Committee, Ministry of Education, Kajiado County and the guardians/parents

Results: Two hundred and sixty-nine adolescents aged between 13-15 years were included in the study with one hundred and seventy-eight (66.2%) females and ninety-one (33.8%) males. The water fluoride varied from 0.8mg/l to 15.0mg/l according to the source from the school the individual attended. The household fluoride ranged from 0.5-15mg/l.

The prevalence of dental fluorosis was 67.7% with household water fluoride being the most influential predictor of dental fluorosis. The mean IE of those from low water fluoride areas was 104.9+/-14.61; medium water fluoride areas were 106.3+/-13.6 while those of high water fluoride area were 97.8+/-12.5. When the household water was used to categorise, the mean IE was 107.5 for low household water fluoride and 96.2 for both medium and high household water fluoride. There was a difference in IE of adolescents living in low fluoride when compared to those living in high fluoride areas. There was no difference in means between low and medium fluoride areas. There was a difference in IE for individuals with dental fluorosis and those without; those without having higher mean IE (103.87) than those with dental fluorosis (99.044)**.** WM for the fluoride concentrations was different from those

in low water fluoride having a higher mean WM than those with high household water fluoride.

Similarly, the differences in the means for working memory for the children in the medium and high fluoride areas were significant. However, a comparison in the means for working memory between the children in the low and high fluoride areas was not significant. There was a difference in working memory between populations with dental fluorosis and those without dental fluorosis.

There was a significant association between prevalence and severity of dental fluorosis and the water fluoride content.

Conclusion: Children who were exposed to fluoride were at the risk of developing impaired intellectual efficiency, which also affects IQ.

Recommendations: water supply should be given priority by the authorities and education and awareness also given priority. More studies need to be conducted in this area.

Limitations: The survey was across-sectional, and it may not be representative of the effect of fluoride on children from birth up to adolescent if it was controlled and longitudinal

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

It has been reported that fluoride concentrations of 0.5 to 1 milligrams per litre (mg/l) in water have been observed to reduce dental caries(1,2). Dental caries is defined by the World Health Organisation (WHO) as localised post-eruptive pathological process of external origin involving the demineralisation of the hard tooth tissues which develop into cavities(3). However, chronic intake of higher concentrations of fluoride of 1.5mg/l and above has been reported to cause varying degrees of severities of dental and skeletal fluorosis(4). WHO defines dental fluorosis as the hypomineralisation of tooth enamel caused by ingestion of excessive fluoride during the period of enamel tissue formation? The fluorotic lesions appear as a range of chalky white in enamel on the eruption in some cases associated with varying degrees of intrinsic tooth discolouration and later on enamel loss after tooth eruption.

Hypomineralisation in fluorosis is as results of formation of fluorapatite crystals and not hydroxyapatite. The fluorapatite crystals have higher porosity and are brittle(5,6). The most vulnerable age where excessive exposure leads to dental fluorosis is from birth to about eight years(7). Excessive intake of fluoride results in bone deformity due to increased accumulation of fluoride in the bones. The effect of fluoride on developing teeth is not reversible, but it's preventable(8). Water is a significant component of life; according to Mitchell et al., the human body has up to 67.8% water; the brain and heart have up to 73%, the lungs approximately 83%, the skin 64%, muscles and kidneys 79%, bone 31% and teeth about 5% water(9). All body tissues are influenced by water in a significant way either during formation, growth or physiological functions.

Water is a source of fluoride to the human body(4). Fluoride is a chemical compound that occurs naturally on the earth's crust. It is formed during rock formation and is a chemical ion of fluorine. Due to problems of inadequate necessary infrastructure for water treatment, high fluoride concentrations are a problem in developing countries.

The Kenya National Bureau of Statistics (KNBS) has documented that most of the population in Kenya rely on underground water which has been described as among others water fetched from wells and boreholes(10). There is an inadequate quality supply of water with low fluoride concentrations. Some parts of the Rift valley of Kenya, for example, Nakuru has a water demand of 45000m^3 of which only 6000 to 10000m^3 being obtained from surface water sources, while the rest of the water from wells and boreholes and it contains high concentrations of fluoride(11). Studies conducted in Kenya have reported that millions of Kenyans using water with high fluoride content are vulnerable to skeletal and dental defects and other medical-related conditions because of high levels of fluoride in their drinking water(11). The maximum WHO recommended fluoride dose in drinking water is 1.5 milligrams per litre (mg/l). However, most underground sources contain fluoride levels that are higher than these(11). In addition to the dental and skeletal deformities caused by chronic intake of high doses of fluoride, other toxic effects of high doses of fluoride are neuronal dysfunction and synaptic injury through free radical production and lipid peroxidation(12). Studies have shown that excessive fluoride may lead to lower intelligence quotient. Hence, high fluoride doses are being counted among other contributing factors lower intelligence quotient. Studies have been conducted in Kenya, where a high prevalence of dental fluorosis affecting up to 21% and 94% of the population were reported. In most case, the individuals in the fluorosis endemic regions have up to 50% of their teeth(13,14). No study has been conducted in Kenya to show the impact of chronic intake of high doses of fluoride on the intellectual efficiency and working memory of adolescents in Kenya.

1.2 LITERATURE REVIEW

1.2.1 DENTAL FLUOROSIS INDICES

Several indices have been used to report the severity of dental fluorosis in communities in high fluoride areas.

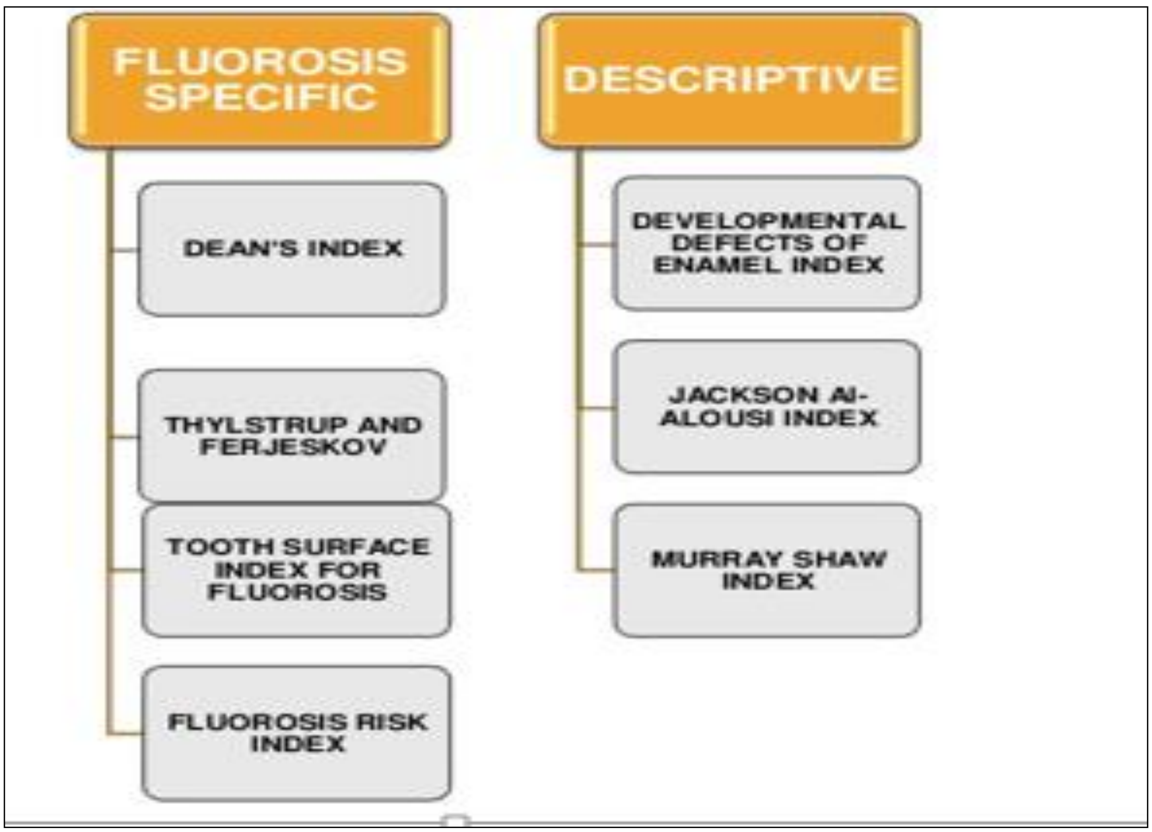

Figure 1.1: Classification of fluorosis measuring indices(15)

The major ones us

ed currently include;

a) Deans Index(16) (Trendley H. Dean 1934)

The six-point scale was used to categorise dental fluorosis. It was considered an ordinal scale although no numbers were used and each receives a score according to the clinical appearance of the two most affected teeth.

Code 0- Normal; usual translucent, smooth, glossy and pale creamy white

Code 0.5- Questionable; slight aberration from translucency to occasional white spots

Code 1- Very mild; small opaque paper white areas scattered irregularly over the teeth not involving more than 25% of the tooth.

The lesions were less than 1-2mm opacity at the cusp tips of the bicuspids or molar.

Code 2- Mild; opaque white areas more extensive but less than 50% of the tooth

Code 3- Moderate; all enamel surfaces of the teeth are affected and surfaces subjected to attrition show wear.

Brown staining is frequently a disfiguring feature

Code 4- Severe; all enamel surfaces affected

Marked hypoplasia

The primary diagnostic sign is discrete or confluent pitting and widespread brown stains with a corroded like appearance.

b) Thylstrup and Fejerskov (TFI) (1978) and Horowitz (1984) indices(17).

The TF index shall be the index of choice in this study and shall be abbreviated as TFI because of its practicality(17). The 1988 TFI modified by Fejerskov shall be used where only one surface is examined

Thylstrup-Fejerskov (TF) Index is scored as follows(17)**:**

0. Normal translucency of enamel remains after prolonged air-drying.
1. Narrow white lines were corresponding to the perikymata.
2. *Smooth surfaces:* An increase in clear lines of opacity that follow the perikymata. Occasionally confluence of adjacent lines. *Occlusal surfaces:* Scattered areas of opacity <2 mm in diameter and pronounced opacity of cuspal ridges.
3. *Smooth surfaces:* Merging and irregular cloudy areas of opacity. Accentuated drawing of perikymata often visible between opacities. *Occlusal surfaces:* Confluent areas of marked opacity. Worn areas appear almost normal but usually circumscribed by a rim of opaque enamel.
4. *Smooth surfaces:* The entire surface exhibits marked opacity or appear chalky white. Parts of the surface exposed to attrition seem less affected. *Occlusal surfaces:* Entire surface exhibits marked opacity. Attrition is often pronounced shortly after the eruption.
5. *Smooth surfaces and occlusal surfaces:* Entire surface displays marked opacity with focal loss of outermost enamel (pits) <2 mm in diameter.
6. *Smooth surfaces:* Pits are regularly arranged in horizontal bands <2 mm in vertical extension. *Occlusal surfaces:* Confluent areas <3 mm in diameter exhibit loss of enamel — marked attrition.
7. *Smooth and occlusal surfaces:* Loss of outermost enamel involving <1/2 of the surface.
8. *Smooth and occlusal surfaces:* Loss of outermost enamel involving >1/2 of surface
9. *Smooth and occlusal surfaces:* Loss of main part of enamel with a change in the anatomic appearance of the surface. The cervical rim of almost natural enamel is often noted.

1.2.2 RISK FACTORS FOR DENTAL FLUOROSIS

Several risk factors are associated with dental fluorosis. A similar amount and dose of fluorosis may lead to dental fluorosis of varying severity in different individuals. The severity may be due to among other factors; the age of the individual, amount of time of overexposure, nutrition, weight, among others.

The optimum level of water fluoridation is 1.0 to 1.5mg/l or 0.05 to 0.07mg/kg/day. When there is ingestion above this level, it was considered unsafe and increased the risk of dental fluorosis(4,18). Firempong et al. showed a strong association between dental fluorosis and high fluoride levels in the underground water on the Bongo community(19). The finding was collaborated by Opinya that showed high fluoride concentration in underground sources of water, especially the well which was 0.2 to 3 mg/l and borehole with1.0 to 9.3 mg/l(20).

Tea brewed from 3.9gms tea leaves had 5.0 ppm of fluoride(21), which brings diet as a risk factor. The high fluoride in tea ingested in Tibet where brick tea type of fluorosis was more in those who took brick tea than the Chinese average(22).

The altitude also is a risk factor in fluorosis(22,23). Those who live in higher altitude regions tend to have increased risk of fluorosis. The increased risk of developing dental fluorosis may be due to hypoxia as at high altitudes, which may reduce urinary excretion of fluoride, thus leading to its increased retention.

Malnutrition was also found to increase dental fluorosis. Children who were found to have the malnutrition, i.e. low height for their age had a higher chance of having dental fluorosis(24). Therefore, children with poor nutrition have a higher chance of developing dental fluorosis.

The climate also affects dental fluorosis in that people staying in the tropics tend to consume more water. If it has fluoridated, they will, therefore, be exposed to more fluoride, thus dental fluorosis(25). High rainfall areas with high water fluoride may have less fluorosis because of the heavy rain, which reduces water consumption and dilutes the sources of water.

1.2.3 EFFECTS OF FLUORIDE CONTENT IN WATER ON DENTAL FLUOROSIS

The content of fluoride in water has been shown to affect the level of dental fluorosis. Heller et al. showed that an increase in water fluoride led to an increase in the prevalence of dental fluorosis(26). Prevalence of 13.5% was shown for levels less than 0.3ppm, 21.7% for 0.3ppm to less than 0.7 ppm, 29.9% for 0.7ppm to 1.2ppm and 41.4% for more than 1.2ppm.

In the Guadiana Valley North-western Mexico, a quantitative assessment of dental fluorosis and it was noted that in areas where the fluoride concentration in the drinking water was higher than 12 ppm, all the children had dental fluorosis and 35% suffered severe damage to the teeth(27).

Shekar et al. found that in the endemic fluoride belt of Andhra Pradesh, the prevalence and severity of dental fluorosis increased with increase in the concentration of fluoride in the water. It was 100% in high fluoride areas(28).

1.2.4 THE PREVALENCE OF DENTAL FLUOROSIS

The prevalence of dental fluorosis differs from region to region depending on the risk factors. The overall prevalence of dental fluorosis in Kenya is 41.4%, according to the Kenya National Oral Health Survey of 2015(29). It was higher among the males (41.3%) than the females (38.5%). The 12-year-olds and the rural residents had a higher prevalence of dental fluorosis. In 1993 Ng'ang'a e.t. al. found 18% of the children between six and eight years had fluorosis, while 76% of 13 to 15-year-olds had dental fluorosis in the primary dentition(30). There was also no gender preference ($p>0.05$). Makhanu found a prevalence of

68.1% of dental fluorosis in Kenya(31). Mutave in 2016 found an overall prevalence of 93.4% among the 12-15-year-olds (14). According to regions in Kenya, it was found that the former central province had the highest prevalence, followed by former Eastern province and finally Rift Valley(32). In this study, the overall prevalence of fluorosis was 37.9%. In a study done in Juja, 50.7% were found to have dental fluorosis by Waweru(33).

A study was done in the Main Ethiopian Rift (MER) and found a fluorosis prevalence of 91% with 45% having severe fluorosis. Dental fluorosis and urinary fluoride were also found to be different in children exposed to similar ground sources. The absorption of high urinary fluoride and the development of dental fluorosis shows is an indication that exposure to fluoride in water and other sources differs from one individual to another due to other factors(4).

In Nigeria, it was found that the prevalence of dental fluorosis was significantly higher in those districts that have high altitude, so was the severity(23).

Beltran et al. found a prevalence of 56.3% in Mexico with a varying degree of severity(34).

Molino-Frechero et al. found an overall prevalence of 59% with a mean fluorosis score of 0.887+/- 0.956, and it had an association with frequency of brushing and lack of supervision from parents(35).

Jagan et al. found that the prevalence of fluorosis varied from 1.4% to 29.4% depending on the level of fluoride(36).

1.2.5 PATHOPHYSIOLOGY OF FLUORIDE TOXICITY

Everett et al. showed that fluoride acted through the Mitogen-Activated Protein Kinases signalling pathway activated following environmental stress. This pathway, when activated leads to several responses among them cell proliferation, differentiation, survival and apoptosis. It is also very likely that chronic exposure to high doses of fluoride may directly affect ameloblasts at maturation phase resulting in the retention of proteins in the enamel matrix; and subsequently reduced the removal of enamel matrix during enamel maturation. It may also lead to the initiation of the endoplasmic reticulum stress response pathway(37).

The subsurface hypomineralisation maybe because of delayed amelogenin removal during the early maturation stage of enamel formation with evidence pointing towards reduced proteinase activity hence reduced hydrolysis of amelogenin. There could also be a direct effect of fluoride on proteolytic activity or secretion of proteinase. Alternatively, there may be a reduction in proteinase effectiveness due to other changes in protein or mineral content of the fluorosed mineral matrix(38).

In a study where tissue culture of the odontoblasts was done, Wurtz found that up to 1 millimolar of sodium fluoride DNA accumulation was not inhibited. Still, above three millimolars the odontoblasts detached from their support and failed to proliferate. At low NaF, i.e. 1mM the intracellular compartment was, but necrotic features were evident at NaF above three mM. Genetically even at low fluoride concentration, the RNAs encoding for extracellular matrix proteins and cell membrane-associated proteins were reduced 10-fold(39).

Guo Hua S et al. found that fluoride exposure on Leydig cells had widespread effects on cell proliferation, apoptosis and signalling pathway changes. A high dose of fluoride inhibited cell proliferation by stress-induced apoptosis by affecting the expression of levels of stress response factors. The reduction in the stress response factors also changed the signal transduction components. Moreover, the apoptosis-related proteins, including Bax, B-cell lymphoma 2, caspase 3/9, were affected(40).

1.2.6 THE EFFECTS OF HIGH FLUORIDE IN WATER ON INTELLECTUAL EFFICIENCY AND WORKING MEMORY

Working memory is part of what is tested during IQ testing(41). Heuvel et al· found a robust positive association between the efficiency of the brain network (intellectual efficiency) and intellectual performance(42). Due to the short period of the study, the complete IQ test was not done. However, two tests which have a definite relation to IQ; intellection efficiency and working memory were examined. Most of the studies in the review have had the complete IQ test was done (39).

Research has been conducted to establish the IQ of school going children. Sebastian et al. did a study about the effect of fluoride on IQ and found a statistically significant relationship between the levels of fluoride and IQ ($p<0.05$). Those in high fluoride village, the proportion with below-average IQ, i.e. 90 was larger in comparison to low and normal fluoride region. She investigated 405 children aged between 10 to 12 years living in three villages where a fluoride concentration of 2.2 mg/L was considered as high, while 1.2 mg/L fluoride in water was considered normal and 0.4 mg/L of fluoride was considered as normal. (43)

Poureslami et al. also did a study among 120 children age 7 to 9 years in Iran. The children in high fluoride area had a significantly lower IQ of about 91 and about 97 in the lower fluoride areas ($p=0.028$). The fluoride concentration of 2.38 mg/l was considered high, while 0.41 mg/L of fluoride was considered low. The finding, therefore, led to the conclusion that excessive fluoride intake may increase the ability to produce harmful effects on the developing brain(44).

Seraj et al. found that the mean IQ decreased from an average of 97.77 for a normal fluoride group to 89 for medium fluoride to 88 for the high fluoride group ($p=0.001$). Where Control = 0.8+0.3 mg/l Medium fluoride = 3.1+0.9 mg/l High fluoride = 5.2+1.1 mg/l. Therefore, children who live-in high-water fluoride areas showed impaired development of intelligence. The impaired development of intelligence further shows that high water fluoride affects a child's intelligence(45).

A study done in Pradesh state in India among 12-year-olds found that in children in endemic fluorosis areas were at higher risk of impaired intelligence development. It was found that urinary fluoride is a predictor of intelligence and intelligence reduced as water fluoride levels increased(46).

Ding et al. showed that there is a dose-response relationship that was established between urine fluoride and IQ score. The dose-related fluoride was also the same for dental fluorosis. He confirmed that with an increase in 1gm/l of urinal fluoride, there was an IQ drop of 0.59 points ($p<0.0226$) and there was also a significant dose-related severity of dental fluorosis and the fluoride concentration in the urine.

Phyllis J. Mullenix in the 1990s researched the neurotoxicity of fluoride. She started on animal models, and the results were that brain function was impacted by fluoride. She also found that effects on the brain age-dependent and also depended on fluoride accumulated in tissues(47).

PK Shivaprakash found a significantly higher IQ for children without dental fluorosis than for those with dental fluorosis(48). However, the IQ did not vary with the severity of dental fluorosis by Dean's index.

1.2.7 DEVELOPMENT OF FLUORIDE NEUROTOXICITY

Yu Y et al. investigated 20 fetuses ten each from high and low fluoride areas whose mothers had high urinary fluoride and dental fluorosis for those from high fluoride areas. Due to the passage of fluoride through both the placental and blood-brain barrier, the fetuses from high fluoride area had raised brain and bone fluoride levels. The fetuses from the endemic high fluoride areas were found to have high levels of epinephrine and decreased levels of norepinephrine. The low levels of norepinephrine lead to reduced levels of alertness, and emotions. Also, interfered with are the cerebrocardiovascular functions, which are the inability to keep a healthy state of activation in the central nervous system (CNS). However, the increased level of epinephrine might be due to decreased metabolic enzymes or inhibition of the pathway that converts it to norepinephrine(12).

Another study found that healthy Purkinje cells in fetuses from endemic fluoride areas were disorganised and had a thicker granulated layer in comparison to those in low fluoride areas which were well organised in the cerebellum and single or parallel lines(49). Those in high fluoride areas also had higher nuclear to cytoplasm ratio in the brain cones, hippocampus cones and Purkinje cones. On further scanning electron microscopy, there was a decrease in the neurons of the brain cortex, reduced numerical, volume and surface density for the fetuses from endemic fluorosis areas. They, therefore, concluded that fluoride stunts neuron development and negatively affect developing CNS.

The brain cells of fetuses from endemic fluoride areas were found to have swollen mitochondria of the nerve cells. The expanded granular endoplasmic reticulum, the grouping of chromatin, damage to the nuclear envelope, fewer synapses, decreased mitochondria and vesicles within the synapse and damaged the synaptic membrane. All these lead to an abnormal synaptic function which influences the development of intellect after birth(50).

In a cross-sectional study on neurobehavioral effects of excess fluoride and found that the group exposed to fluoride had significant impairment in reaction time, pursuit aiming, digit span, Benton visual retention and digit memory(51).

American national research council did a case report. Twelve cases that had people exposed to fluoride of all ages showed sequelae of lethargy, weakness and impaired ability to concentrate and in about half of the memory problems were reported. In some cases, symptoms would disappear with the elimination of exposure to fluoride and reappear on re-exposure(52).

Jing L et al. evaluated the neurobehavioral development and neurodevelopment toxicity of fluoride. They found significant differences in the neonatal behavioural, neurological assessment score and neonatal behavioural score between the fetuses born in endemic fluorosis areas and the control. The high fluoride group had impaired neurobehavioral capability and agonistic muscle tension. The neonates from high fluoride areas also lagged in neurobehavioral skills like auditory direction reactions, non-biological and biological visual activity. The reduced neurobehavioral skills show high fluoride levels adversely affect the neurobehavioral development of neonates with a negative impact on the future body and intellectual development(53).

Guo Z et al. found that workers exposed to fluoride in high levels had deficits in attention, auditory retention, physical ability and some had abnormal emotional states thus high fluoride affects both cognitive and autonomic functions(54).

1.2.8 INDEX FOR DETERMINING IE AND WM

Wechsler Intelligence scale-revised version has also been used. In these four leading indices are measured, i.e. verbal comprehension index, perceptual reasoning index, working memory index and processing speed index. The indices are scored, and it generates a full-scale IQ (41). The instrument of choice shall be Wechsler Intelligence scale for children 5th edition (WISC-V). The author is David Wechsler, and the 5th edition was published in 2014. It is used for children aged between 6 years and 16 years and 11 months. It needs a paper and a pencil, but there is a digital version. The completion time of the core subtests is 48 to 65 minutes. The primary index scales include; Verbal comprehension index, Visual-spatial index, working memory index, Fluid reasoning index and Processing speed index(41). The individual tests are as described in figure 1.2.

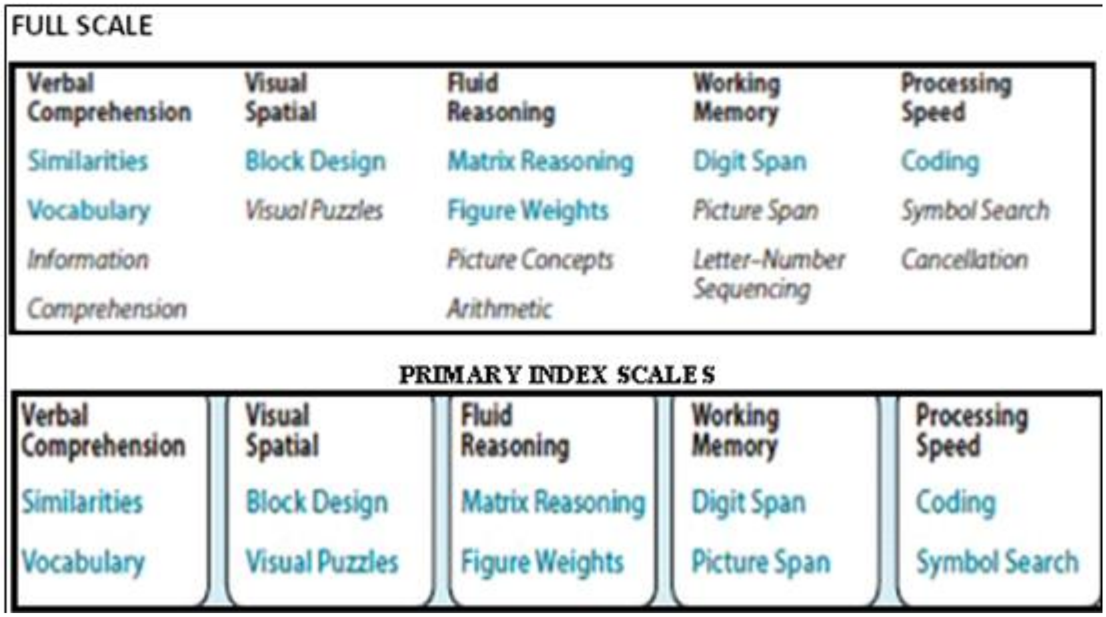

***Figure 1.2: WISC V Framework* (55)**

The working memory shall, therefore, be done using WISC V.

The intellectual efficiency shall be determined by the Wide Range Achievement Test 4 by Gary(56). The test has three subtests thus reading, spelling and arithmetic. The reading included recognising and naming letters and pronouncing words out of context. Grammar involves writing names, writing letters and words to dictation while arithmetic involved counting, reading number symbols, solving oral problems and performing written computations.

1.3 STATEMENT OF THE PROBLEM

Dental and skeletal fluorosis is endemic in some areas. However, there are no reports on the intellectual efficiency and working memory in children living in high fluoride areas or low fluoride area in Kenya. Therefore, this study filling the gap in the knowledge on the relationship between top fluoride source in water, dental fluorosis observed and the intellectual efficiency and working memory of adolescents in North Kajiado Kenya. To address the knowledge, gap a study on the relationship of dental fluorosis, intellectual efficiency and working memory was designed for a comprehensive understanding of oral health in public health, mental health and education.

Hence the proposed question of “is there a difference in the intellectual efficiency and working memory of children living in low and high fluoride areas which have endemic dental fluorosis?”

1.4 JUSTIFICATION

The study intended to contribute to scientific knowledge with severity and prevalence and epidemiological associations between dental fluorosis, intellectual efficiency and working memory. It is perceived that the results from the study may inform policy in the ministries of education, health, water and education. The study was conducted in Kajiado North since it had both high and low fluoride area on 13-15-year-old adolescents who at this stage of intellectual development are formalising their thinking patterns.

1.5 STUDY OBJECTIVES

1.5.1 Broad Objective

The main of the study was to determine the relationship of dental fluorosis, intellectual efficiency and working memory if any of adolescents who were born and raised in North Kajiado.

1.5.2 Specific Objectives

1. To determine the fluoride content and heavy metals in drinking water in from ground and surface sources Kajiado North sub-county
2. To determine the intellectual efficiency and working memory of adolescents living and learning in low fluoride (≤1.0mg/l), medium fluoride (≥1.1mg/l and ≤2.0mg/l) and high fluoride ≥2.1mg/l areas in North Kajiado sub-county.
3. To establish the severity of dental fluorosis in adolescence 13-15 years, in using water with low (≤1.0mg/l), medium (≥1.1mg/l and ≤2.0mg/l) and high fluoride ≥2.1mg/l areas in North Kajiado sub-county.
4. To compare the intellectual efficiency of adolescents living in a low (≤1.0mg/l), medium (≥1.1mg/l and ≤2.0mg/l) and high fluoride ≥2.1mg/l areas in North Kajiado sub-county.
5. To compare the working memory of adolescents living in a low (≤1.0mg/l), medium (≥1.1mg/l and ≤2.0mg/l) and high fluoride ≥2.1mg/l areas in North Kajiado sub-county.

1.6 HYPOTHESIS

1. There is a difference in intellectual efficiency of adolescents with normal teeth living in a low (≤1.0mg/l) fluoride area when compared to the intellectual efficiency of adolescents aged 13-15years residing in a medium (≥1.1mg/l and ≤2.0mg/l) and high fluoride ≥2.1mg/l areas in North Kajiado sub-county
2. There is a difference in working memory of adolescents with normal teeth living in a low fluoride area when compared to the working memory of adolescents living in a

medium (≥1.1mg/l and ≤2.0mg/l) and high fluoride ≥2.1mg/l areas in North Kajiado sub-county

3. There is an association between varying degrees of severity of dental fluorosis and the intellectual efficiency of adolescents living in a low (≤1.0mg/l), medium (≥1.1mg/l and 2.0mg/litre of fluoride) and high fluoride ≥2.1mg/l areas in North Kajiado sub-county

4. There is an association between varying degrees of severity of dental fluorosis and the working memory of adolescents living in a low (≤1.0mg/l), medium (≥1.1mg/l and 2.0mg/litre) and high fluoride ≥2.1mg/l areas in North Kajiado sub-county

1.7 STUDY VARIABLES

1.7.1 Independent variables

1. Age
2. Gender
3. Level of fluoride in water

1.7.2 Dependent variables

1. Intellectual efficiency
2. Working memory
3. Dental fluorosis

1.7.3 Confounders

1. Heavy metals

CHAPTER 2

2.0. MATERIALS AND METHODS

2.1 STUDY AREA AND POPULATION

2.1.1 Study area

The site of the survey was in Kenya's public primary schools located in Kajiado County, Kajiado North Sub County, and Figure 2.1.

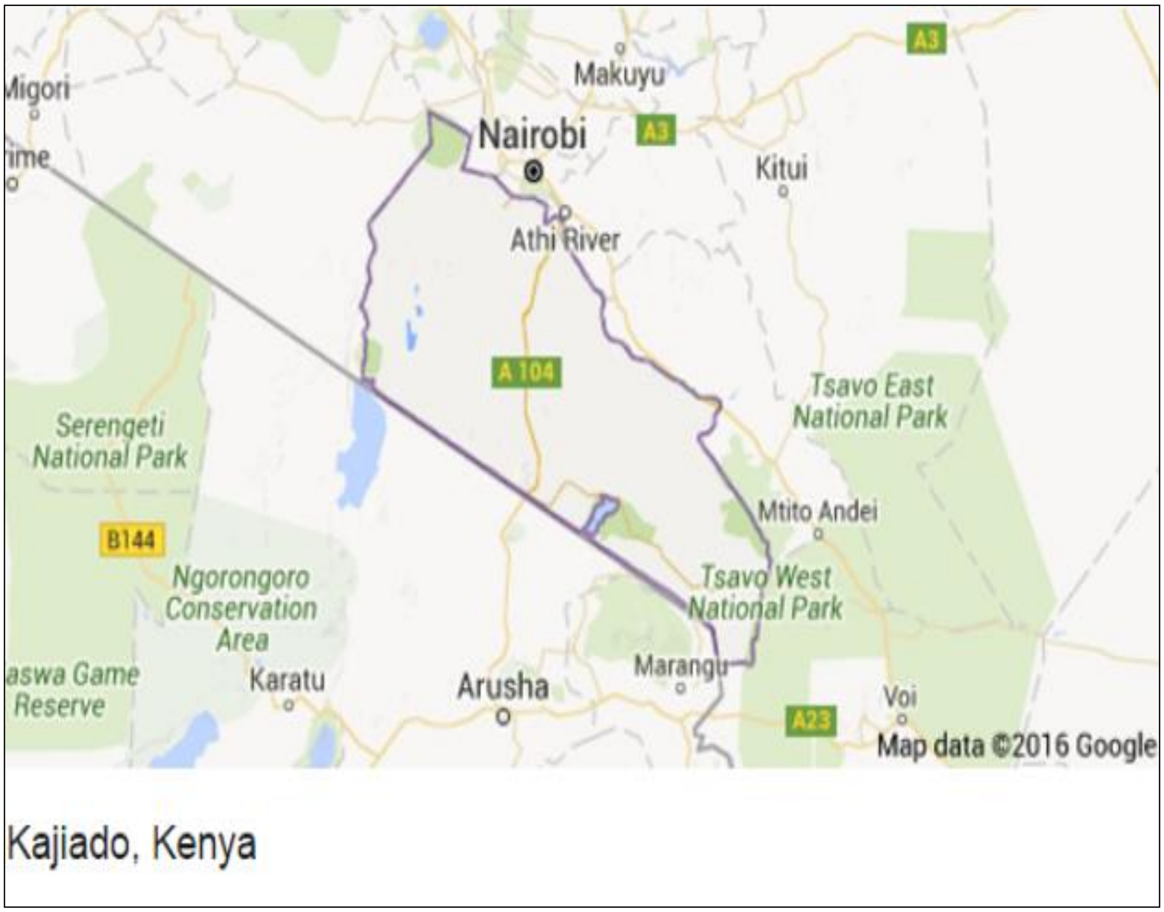

Figure 4.1: Map of Kajiado County and its neighbouring counties illustrating its proximity to Nairobi and population pressure from Nairobi

Figure 2.2: Sub-counties in Kajiado County

Kajiado is one of the counties in the expansive former Rift Valley province of Kenya. It has a population of approximately 687 312 people as of the 2009 census. It has five administrative sub-counties. There were about 523 public and private primary schools in Kajiado County.

2.1.2 Study population

The study population comprised of adolescents aged 13 to 15 years who were born and brought up in Kajiado County Kajiado North Subcounty in the 1st eight years of their lives. Adolescents in day primary schools were recruited. The study was done from October 2016 to February 2017.

2.1.3 Inclusion criteria

1. Aged between 13-15 years in day schools
2. Brought up in Kajiado County Kajiado North sub-county from birth up to the time of the study. Similarly, adolescents whose parents may have moved into the study area when they were aged between one to two years, and they had never migrated in and out of the study area up to the time of the study.
3. Parental consent had been given
4. One group low fluoride (≤1.0mg/l) in the drinking water without dental fluorosis living in Kajiado North
5. Second group medium fluoride (≥1.1mg/l and ≤2.0mg/l) for the adolescents who either had or did not have dental fluorosis
6. Third group high fluoride ≥2.1mg/l with or without dental fluorosis living in Kajiado North
7. Water without heavy metals, i.e. lead metals, arsenic and aluminium.

2.1.4 Exclusion Criteria

1. Existing chronic medical condition
2. Water with heavy metals

3. Failure to meet inclusion criteria

4. Children with learning disabilities.

2.2 METHODS

2.2.1 Study design

The cross-sectional descriptive study design was used to compare the dental fluorosis intelligence efficiency and working memory of adolescents in areas with high, medium and low water fluoride. The areas were divided into three which were low water fluoride equal to or below 1.0mg/l concentration of fluoride, the medium between 1.1mg/l to and including 2.0mg/l and high fluoride areas above and including 2.1 mg/l of fluoride concentration.

The levels of water fluoride, according to the primary water sources in and around the schools, is presented in table 1. The lowest level of fluoride, according to the water source was 0.8mg/l while the highest was 15.0 mg/l. All the water sources around Embul Bul primary school, i.e. Ololaiser, Tosheka and Embul Bul had water fluoride levels that are incredibly high, i.e. above 8 mg/l Table 2.1

Table 2.1: Water fluoride by source around the and in the schools

	Water sample source per school	Concentration (mg/l)
1	Oloolua Primary	0.8
2	Kerarapon Primary	1.0
3	Kiserian Primary (Kiserian Primary)	2.0
4	Saitoti (Ngong township Primary)	2.0
5	Naimasia Ngong (Oloolua/Ngong Township Primary)	3.0
6	Ongata Rongai Primary	3.0
7	Major (Ngong town Primary)	3.0
8	PCEA Nkoroi Water Project (Nkoroi Primary)	4.0
9	Ololaiser (7) water and sewerage (Embul Bul)	8.0
10	Embul-Bul Primary	8.0
11	Tosheka Borehole (Embul Bul)	15.0

The schools in the areas identified for high and low fluoride were selected through systematic random sampling from a list of county schools available on the county website. The schools were divided into those in high, medium and low fluoride areas then schools in each category were randomly selected. The fluoride levels were got from records at the Ministry of water and a study by Katunge(57). However, in each borehole water analysis was also being done.

The primary schools considered were;

High fluoride; Embul-Bul primary school, Ongata Rongai, Nkoroi primary, Ngong town

Medium fluoride; Kiserian primary, Ngong town

Low fluoride; Kerarapon primary school and Oloolua primary school.

2.2.2 Sample size determination (58)

The formula for a comparison of two groups was used to calculate the sample size; where, $N=2(Z_{1-\alpha/2}+Z_{1-\beta})$ p (1-p)/ $(P1-p2)^2$, and N is the desired sample size, while $Z_{1-\alpha/2}$ is the confidence level at 95% (SD 1.96)

$Z_{1-\beta}$ is 1.28 β=10%, i.e. 90% power and P is the mean difference between the prevalence of p_1 (61.8%) and p_2 (38.2%). Therefore, $N=2(1.96+1.28)^2(0.236)$ (1-0.236)/ $0.618-0.382)^2$= 67 per group and 100 per group shall be used to cater for attrition

2.2.3 Sampling procedure

To determine the amount of fluoride sampling of water sources in the region was done. Water samples shall be collected using clear plastic bottles from the water sources and were sending to government chemist for determination of fluoride, and a complete chemical profile was done to rule out heavy metals like lead and arsenic which may affect the intellectual efficiency and working memory of children. The area was then divided into three according to the amount of fluoride in water with low fluoride having 1.0mg/litre and below, medium fluoride from 1.0 mg/l to and including 2.0 mg/l and high fluoride 2.1mg/l and above. Then public schools were randomly selected from the three regions and dental fluorosis, intellectual efficiency and working memory determined. One hundred adolescents were randomly selected from two schools in each of the three regions.

Recruitment strategy

Low, medium and high fluoride areas were identified. The participants in the high fluoride areas with consent and permission and had fluorosis of varying degrees were randomly selected to participate.

In medium and low fluoride areas participants who meet the criteria were randomly selected to participate.

In all area's education on proper oral hygiene, tooth cleaning and prevention of caries were given to both those who participated and didn't participate.

2.2.4 Determination of fluoride concentration in water

Different methods have been used to determine fluoride concentration in the water among them linear potentiometer, standard addition method and ion-selective rod(59). In this study the selective ion electrode for the analysis of fluoride in the water. There was no need for the pre-treatment of samples, and the measuring system is simple, the instruments are relatively low in cost and the method is also susceptible in that a minimal concentration of fluoride ions can be determined by this method(59,60).

2.3 DATA COLLECTION

The children at school were given consent forms to take to their parents. Parental consent was obtained for all the children who were considered eligible after explaining the aim of the study and its nature. A questionnaire was used to gather the child's social demographic information and information on the social, economic status, education, family income, among others by the parent.

Assent was then obtained from the children who brought back the signed consent forms.

2.3.1 Dental examination

The dental examination was carried out by the principal investigator and the level of fluorosis determined according to TFI. The dental exam was done using a dental mirror, probe and disposable gloves under natural light in a classroom with the subject sitting upright on a chair(17).

2.3.2 Working memory

The test was done on participants seated in a school of not more than 30 by the principal investigator. They were spaced out to reduce copying.

The test was done using WISC-V memory subtest. The tests done were digit span, letter and number sequence and picture span to determine the working memory(41).

For digit span, the participants in a group were made to listen to and then write either in forwarding order or reversed order a series of numbers that were read out by the principal investigator and the possible score of 0-14. The letter and number sequence were also done by the principal investigator reading out letters and numbers in a random order, and the participants. Subsequently write the series having rearranged the respective order so that the numbers are first presented in ascending order and the letters alphabetically, and the possible score is 0-21(41).

2.3.3 Intelligence Efficiency Test

The principal investigator administered the test; where a The Wide Range Achievement Test-4 (WRAT4) was the tool of choice, and it was applied in two sessions. An oral for word and letter reading was carried out, and letter reading had fifteen points. Only selected children were doing word and letter reading unless the candidate was not able to pronounce at least five responses correctly. However, the letter reading was not necessary, but full credit was given of fifteen points were awarded. The word reading which is a test of word recognition, had forty words which were read by each, and each word read correctly earned 1 point with a maximum of 40 points to be earned. The word reading was a test of word recognition so unusual pronunciations due to accent, or poor articulation was accepted as correct if the peculiarity was consistent throughout. There was a maximum of 57 points was awarded for letter and word reading(61).

The spelling test was also undertaken where 40 words and 15 letters were spelt. With no more than 30 participants seated in a classroom, words were read out by the principal investigator, and the participants wrote them down in a form provided. One point was awarded for each correctly spelt word and letter to a maximum of 55 (61).

A written arithmetic test was administered for 15 minutes.

The written arithmetic test was then being converted using the WRAT 4 administration manual(61).

2.4 RELIABILITY AND VALIDITY OF INSTRUMENTS

A pilot test was not conducted to determine the validity of the instruments due to time constraints and logistics.

The supervisors calibrated the principal investigator. During the study, the intra-examiner variability was minimised by every 10th child having the dental examination for fluorosis redone and the findings kappa value and 95%confidence intervals (CI) determined. The supervisors randomly called back every 10th participants to check for the reliability. The principal investigator undertook all the clinical examination. The lab shall double test every 20th water sample. The instruments of data collection were examined by the supervisors and any corrections done.

For the intellectual efficiency and working memory was done by the principal investigator, every 10th did a repeat test by the principal investigator and the supervisor and the intra-examined and the inter-examiner variability determined.

2.5 DATA QUALITY AND CONTROL

The principal investigator ensured that the highest quality of data was obtained. The data was only be handled by the principal investigator and the assistant. Access was restricted for confidentiality. The principal investigator did entry and analysis. It was then cleaned and validated. Passwords were used to protect any collected information and the questionnaires adequately kept in a personal drawer that was locked.

2.6 DATA ANALYSIS

The analysis was performed by statistical package for social sciences (SPSS) version 22.0 of windows. The data were subjected to chi-square, Spearman test and analysis of variance (ANOVA). Level of significance $p<0.05$ (confidence interval of 95%). The data were presented using tables, graphs and charts

2.7 ETHICAL CONSIDERATIONS

Ethical approval to conduct research was obtained from the University of Nairobi and Kenyatta National Hospital Ethics committee. The National Commission of Science Technology and Innovation (NACOSTI), Kajiado County Education Office and Kajiado County Commissioner.

The eligible children had the consent of their parents and or guardians sought, and the children's permission was also be sought. They were then recruited and had an explanation of the scope of the study and all that was related to the study study.

Depending on the finding if there shall be found to be a correlation between water fluoride and intellectual efficiency and working memory the parents shall be informed and referred to the County Referral Hospital for the management of the affected child (children). The children who have been severely affected shall be referred to Kenyatta National Hospital for further psychological assessment and management. The county government and the National Government shall also be informed of the results. The results are expected to influence the formulation of policy on fluoride and the health of the children. Also, advice shall be given to change the water source, and the results shall be published in peer-reviewed journals as a contribution towards scientific knowledge which may form a foundation for further research and policy formulation for the international community.

CHAPTER 3

RESULTS

3.0 SOCIODEMOGRAPHIC OF THE PARENTS/GUARDIANS

3.1 Distribution of the children by gender: A total of two hundred and sixty-nine adolescents whose parents had given consent were recruited to join the study. There were ninety-one (33.8%) boys and one hundred and seventy-eight (66.2%) girls. More caregivers for the female adolescents gave consent as compared to boys, figure 3.1.

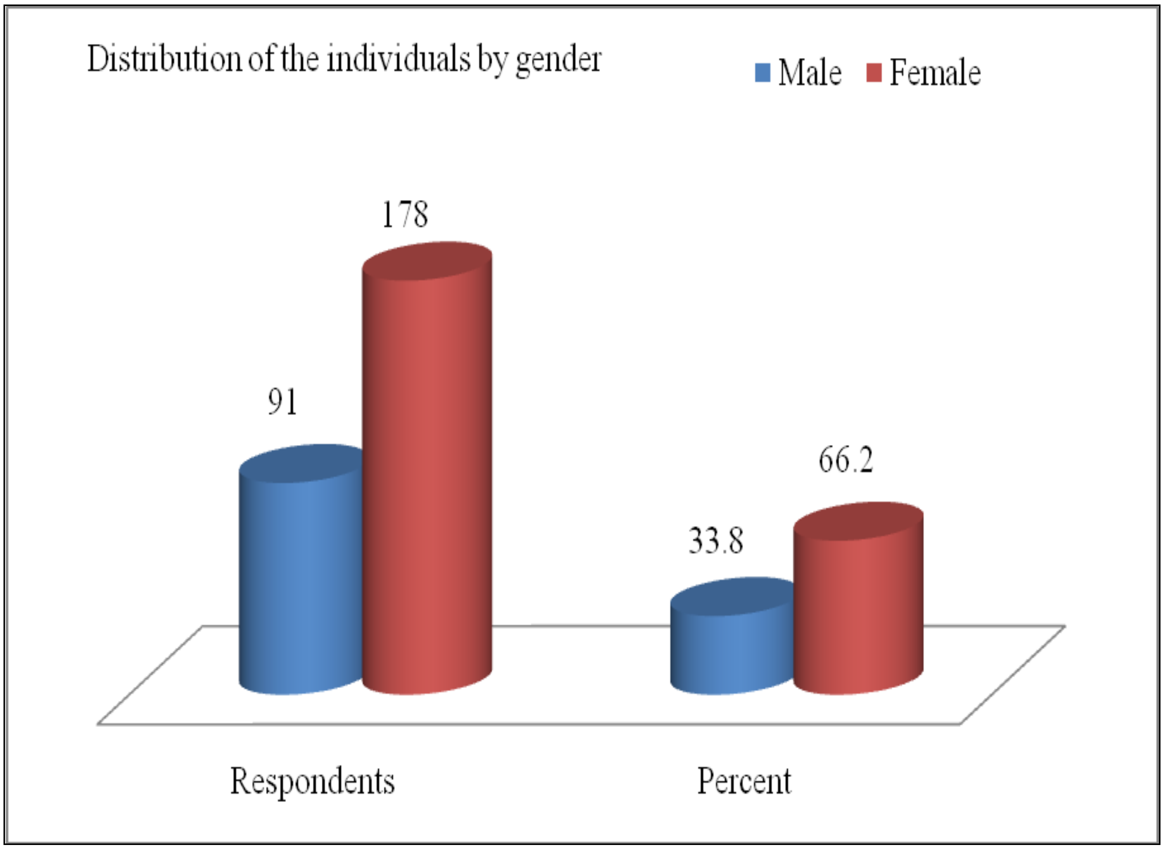

Figure 3.1: Distribution of respondents by gender

Primary school education: The data for seven children for age groups eleven, twelve, sixteen and seventeen years were discarded due to the small sample; hence data of two hundred and sixty-nine children aged 13-15 year is reported in figure 3.2.

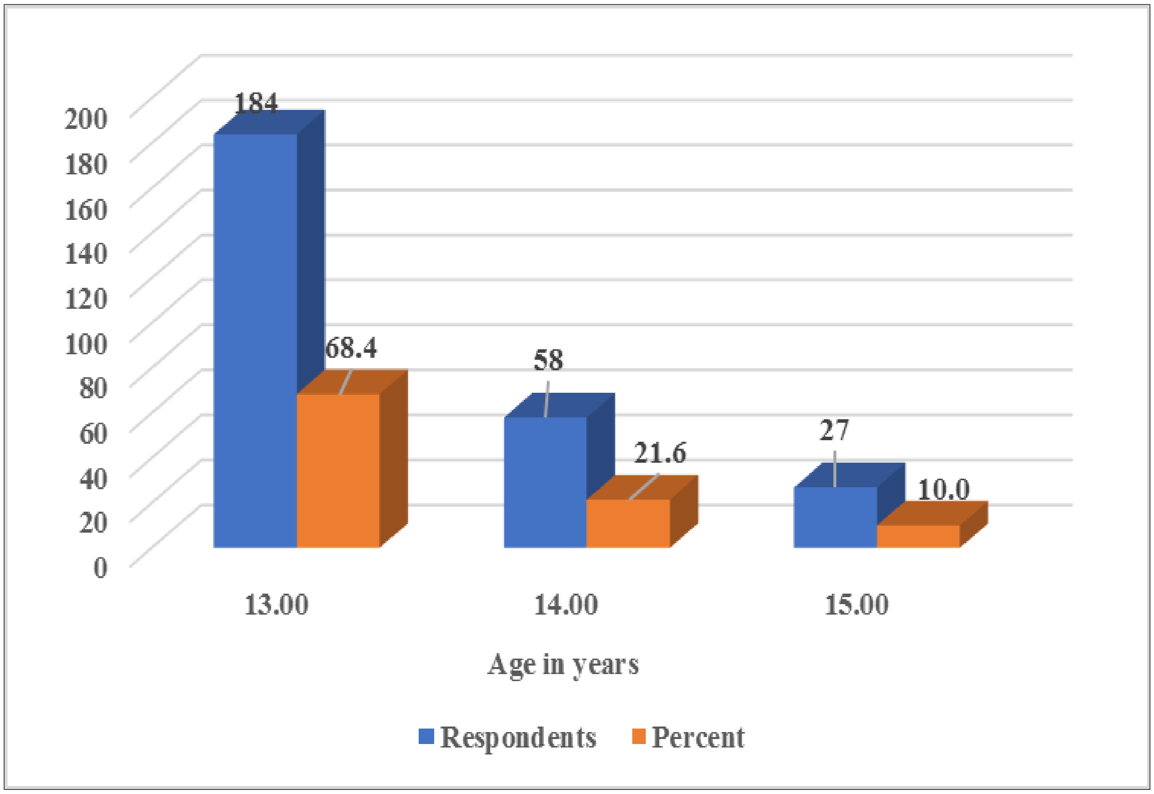

Figure 3.2: Distribution of participants according to age

3.1.1 Migration of the children into the study area: Out of two hundred and sixty-nine individuals involved in study two hundred and thirty-seven (88.1%) was born and raised in Kajiado North Sub- County while forty (11.9%) were born outside the sub-county. Thirty-two respondents who were not born in Kajiado County had sixteen (5.95%) moved in before the age of four years while the other sixteen (5.95%) moved into the sub-county between ages 6-13 years of age. Hence, the majority of those not born in Kajiado County moved in while still young. Also, the high percentage of children born and raised in the community up to the time of the study was an indication that most of the children were exposed to the fluoride and grew up in a similar socio-economic setup, figure 3.3.

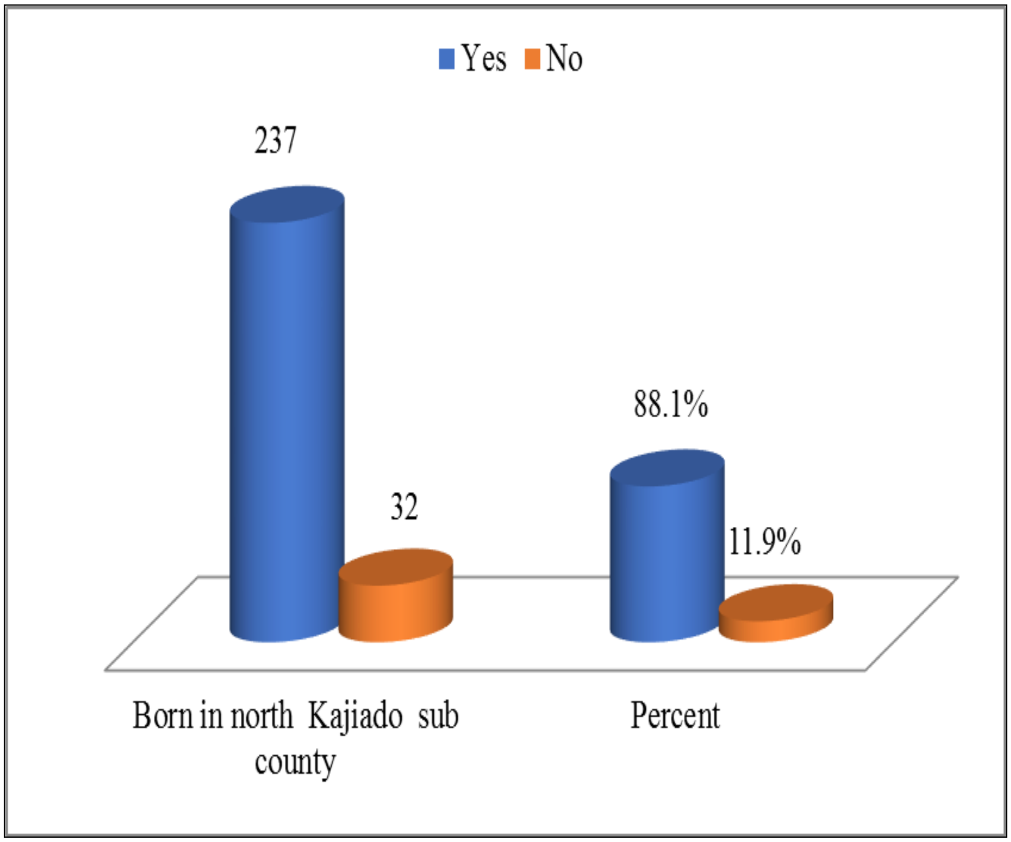

Figure 3.3: The distribution of respondents by place of birth

3.1.2 Placement of the children by school: A total of seven schools participated in the study and the participants per school are as shown. Fifty-nine (21.9%) were from Ngong township primary, fifty-four (20.1%) from Embul-Bul, thirty-eight (14.1%) from Kerarapon, thirty-three (12.3%) from Kiserian primary, thirty-two (11.9%) from Arap Moi primary, thirty (11.2%) from Oloolua primary and twenty-three (8.6%) from Ongata Rongai primary. The schools were picked from areas with different fluoride concentrations but the same cultural and socioeconomic setting, figure 3.4.

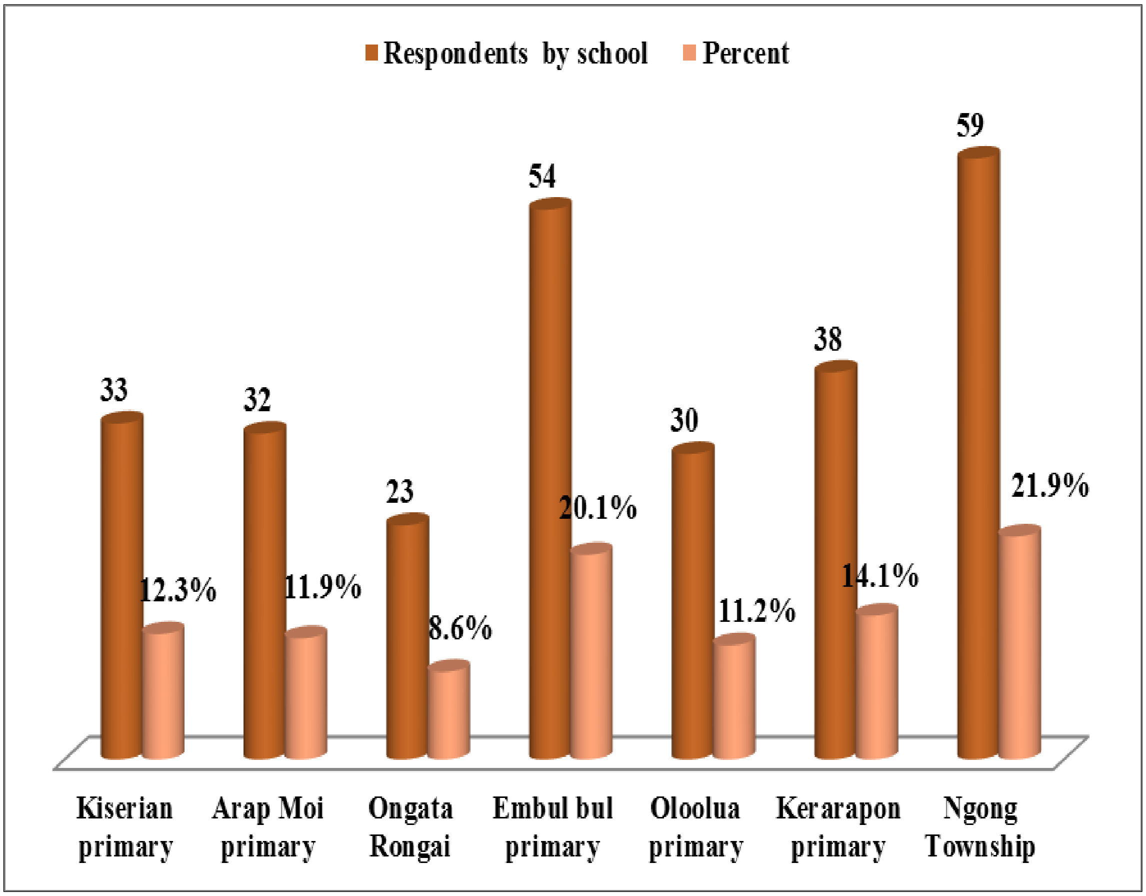

Figure 3.4: The distribution of participants according to the school attended

3.1.3 Family composition: Two hundred and fifty-two (93.7%) of the participants lived with at least one parent while only seventeen (6.3%) lived with guardians, figure 5. Two hundred and twenty-nine (85.2%) of the participants had between one to four siblings, while eleven (4.2%) had more than seven and nine siblings while the mean household was five persons, figure 3.5.

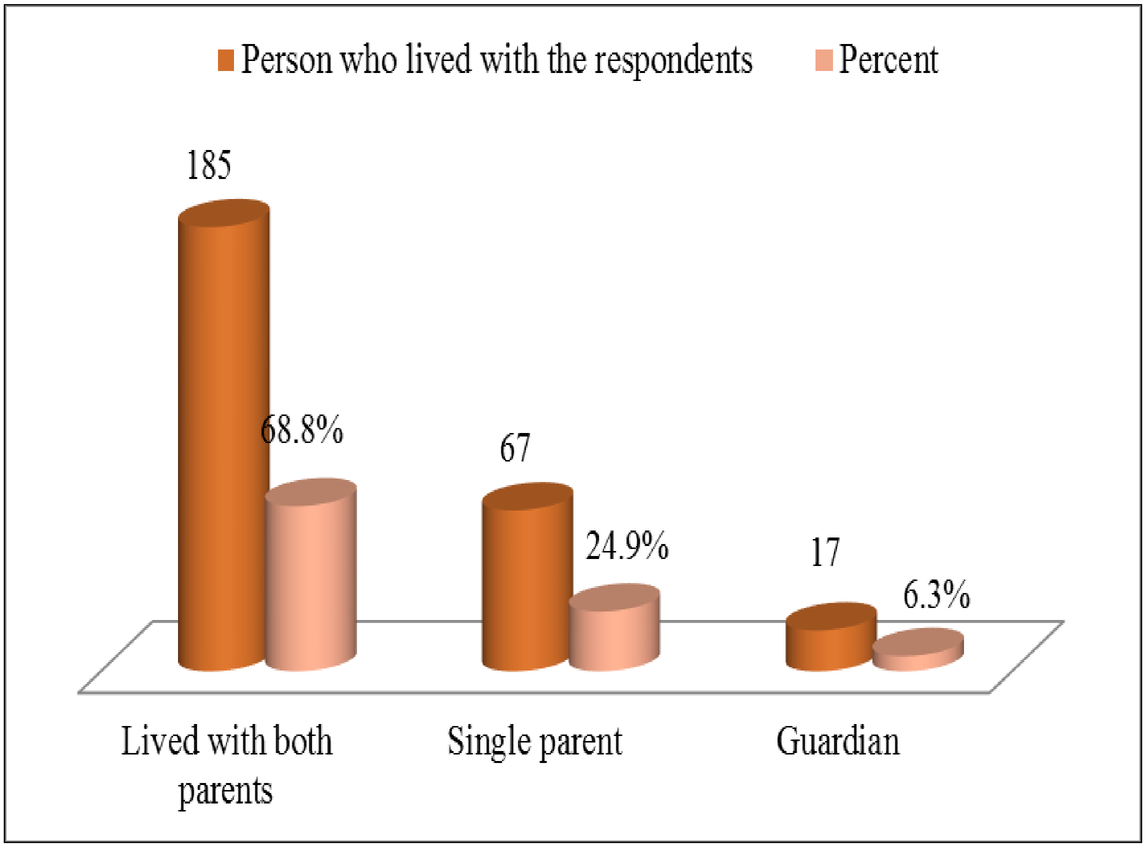

Figure 3.5: The distribution of participants according to whom they lived with

3.1.4 Exposure to Early childhood diseases and Distribution of Early childhood illness: One hundred and fifty-five (57.6%) out of two hundred and sixty-nine of the children had suffered early childhood illness from the time of birth. However, one hundred and fourteen (42.4%) individuals had not suffered from any notable early childhood illness that they could remember or their parents could remember, figure 3.6.

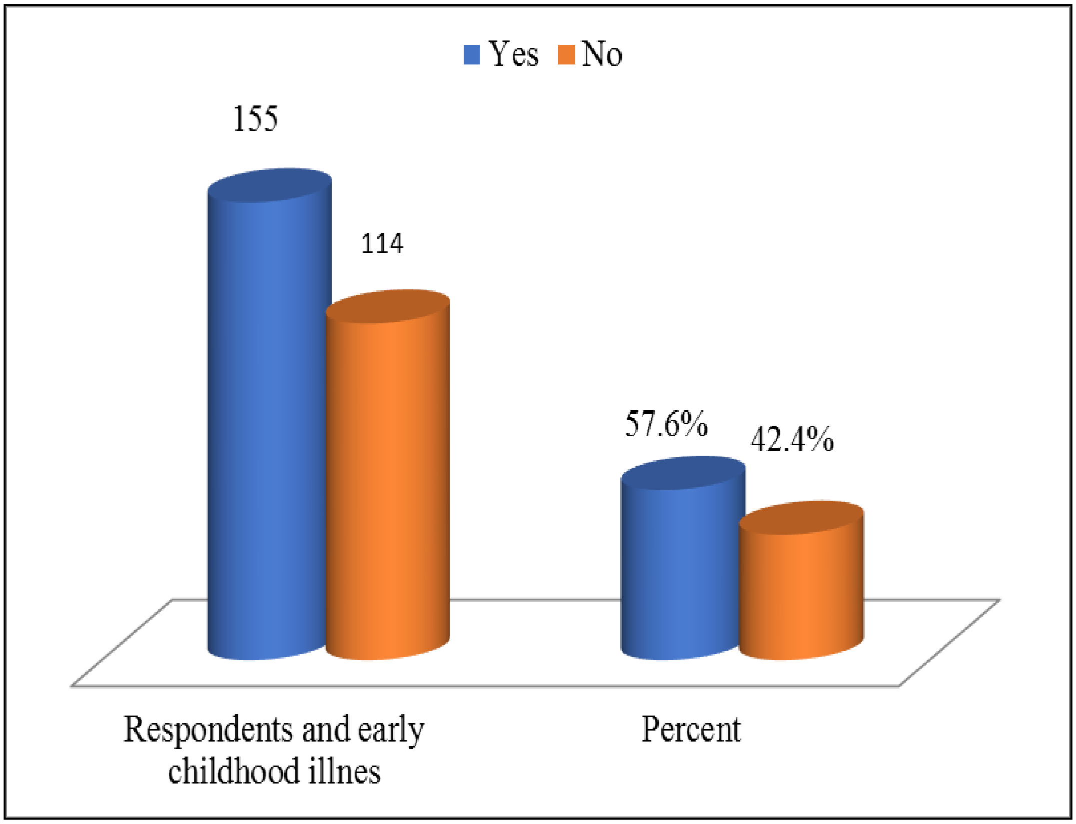

Figure 3.6: The distribution of participants who had suffered from any illnesses

The most common early childhood illness most of the children had suffered from was malaria which had affected 67(24.9%). Chest problems had affected ten (3.7%), typhoid and dental disease had affected six each (2.2%) and 2.2% respectively. Pneumonia had also affected five (1.9%), while amoebiasis 1.5%, eye problems 1.5%, cholera 1.5%, and diarrhoea diseases 1.5%, which had each affected four children respectively. Three (1.1%) children had asthma, ulcers two (0.7%), tonsillitis two (0.7%) children while bilharzia, chickenpox, Fatigue, tuberculosis and flu had each affected one child at 0.4 % per illness. The indicated illnesses are reported to influence the development of the intellect of a child.

The effect has been reported to be noticeable if the ailment was chronic. However, in this study, none of the study participants was chronically suffering from the listed illnesses.

3.1.5 Parental/ Guardian/ Caregiver Education Background: Six (2.2%) parents did not have any formal schooling. One hundred and eight (40.1%) had a primary school level, seventy-three (27.1%) high school and forty-three (15.9%) had college or university education. Thirty-nine (14.5%) of the participants' parents did not answer this question on the level of education, figure 3.7.

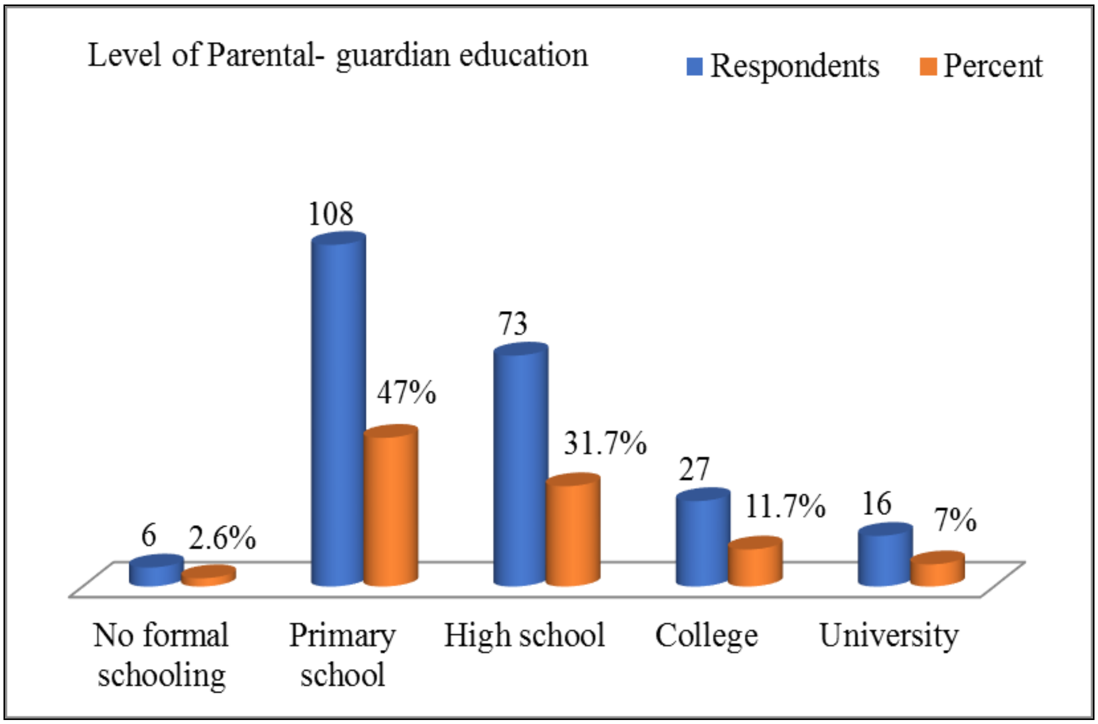

Figure 3.7: The levels of education of the caregivers of the participants

The distribution of the children by age and gender was that in the thirteen year age group fifty-seven (21.2%) were boys while the girls were one hundred and twenty-seven (47.2%). In the fourteen age category there were twenty (7.4%) boys while the girls were thirty eighty(14.1%); while the 15 year age group the boys were fourteen(5.2%) and the girls were thirteen (4.8%), figure 3.8.

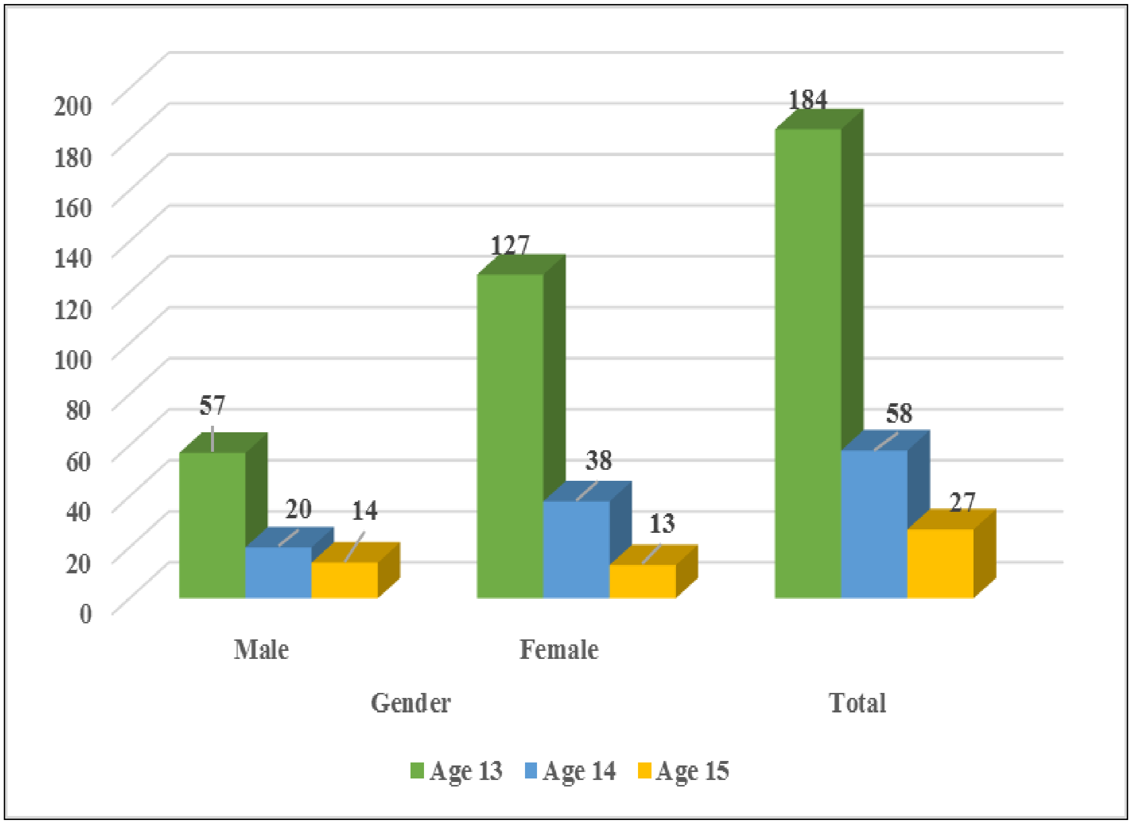

Figure 3.8: The distribution of children by age and gender

3.2. Determine fluoride and heavy metals in drinking water in-ground and surface sources from Kajiado North sub-county.

3.2.0 Water sources: The sources of water were identified as Tap, borehole, Dam/ well, river and other sources. Out of the 269 individuals one hundred and seventy-four (64.7%) used water from the tap, borehole had eighty-two (30.5%), dam/well water was used by nine (3.3%), one (0.4%) individual used river water while three (1.1%) used water from other sources, figure 3.9.

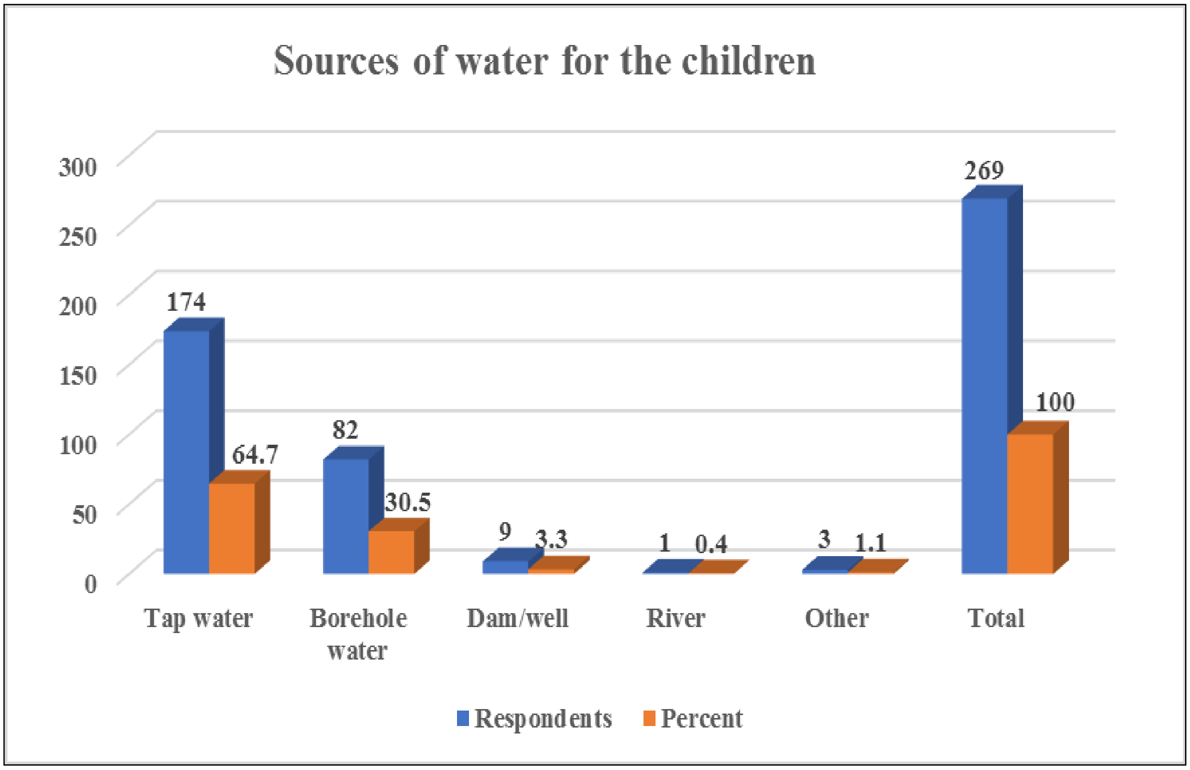

Figure 3.9: Sources of water for participants

3.2.1 Analysis Heavy metals: The water from the chosen schools and the environs was collected and analysed for heavy metal, but the results were negative

3.2.2 Fluoride in surface and groundwater sources

3.2.3. Sources of water around the Schools: The levels of water fluoride according to the primary water sources in and around the schools where the study was undertaken were analysed. The lowest level of fluoride according to the water source was 0.8mg/l from Oloolua primary while the highest was 15.0 mg/l from Tosheka Borehole in Embul-Bul. All the water sources around Embul-Bul primary school, i.e. Ololaiser, Tosheka and Embul Bul had water fluoride levels that are incredibly high, i.e. above 8 mg/l, Table, 3.1.

Table 3.1: The water fluoride content in and around the school water sources

Water sample location	Fluoride (mg/l)
Oloolua Primary dam/well	0.8
Kerarapon Primary borehole	1.0
Kiserian Primary (Kiserian Primary)	2.0
Saitoti (Ngong township Primary) borehole	2.0
Naimasia Ngong (Oloolua/Ngong Township Primary) borehole	3.0
Ongata Rongai Primary borehole	3.0
Major (Ngong town Primary) borehole	3.0
PCEA Nkoroi Water Project (Nkoroi Primary) borehole	4.0
Ololaiser (7) water and sewerage (Embul-bul) borehole	8.0
Embul-bul Primary borehole	8.0
Tosheka Borehole (Embul-bul)	15.0

Each of the two hundred and sixty-nine adolescents were given a labelled plastic bottle and instructed to draw water from the household storage container if they used a borehole. However, those who had running water they were asked to draw water directly from the tap and bring it to school to the principal researcher for fluoride analysis. Fifteen (5.4%) of the household water samples had a fluoride level of 0-0.5mg/l, fifty-four (19.6%) had fluoride level between 0.5-0.8 mg/l and forty-one (14.9%) had a fluoride content of between 0.8-1 mg/l. The water fluoride level between 1-1.8 mg/l was used by forty-two (15.2%) of the population, forty-four (15.9%) of the study population used water with a fluoride concentration which ranged between 1.8-2.5 mg/l while eighty (29%) used water with fluoride above 2.5mg/l. In the study, the low fluoride ranged from 0.1 to 1.0 mg/litre of fluoride and sixty-seven (24.9%) of the adolescents used this concentration of fluoride in their household water. The medium fluoride ranged between 1.1- 2.0mg/litre of fluoride and seventy-nine (29.3%) of the children used household water with this fluoride concentration. The high fluoride concentration involved one hundred and twenty-three (45.72%) adolescents, who used water with a fluoride concentration which ranged from 2.1-15mg/litre of fluoride, table 3.2.

Table 3.2: The distribution of fluoride in household water

Water fluoride levels in water (mg/litre)	Respondents	
	Number of Users	Percent
0-1.0 (low)	105	39
1-2.0(medium)	41	15.2
2.1≤(high)	123	45.8
Total	269	100

In order to determine if the differences in the fluoride in the different water sources were significant an independent samples t-test was done, and a Levine's test for equality of variance showed that the differences in the variation fluoride content in the water with equal variances assumed were insignificant with t (267) =0.377, p=0.706 at 95%CL.

3.2.4 Distribution of the adolescents by water source: There were ninety-one (33.8%) males who used water with a mean fluoride concentration of 3.0198±3.63074 mg/l with standard error of 0.38060 while one hundred and seventy-eight adolescent girls the household water had a mean fluoride content of 2.8348±3.11394 mg/l with standard error of 0.23340. However, an independent t-test showed the differences in the means between the boys and the girls for the water fluoride categories was insignificant t (267) = 0.377, p = 0.706 at 95CL.

3.2.5 The distribution of the children according to the source for household water:

The water fluoride among the 13-year-olds ten (3.72%) took water between 0-0.5 mg/l, thirty-nine (14.5%) took water with fluoride between 0.6-0.8 mg/l, twenty-eight (10.41%) took water between 0.9-1 mg/l, thirty (11.15%) took water with fluoride between 1.1-1.8 mg/l, twenty-eight (10.41%) took water with fluoride between 1.9-2.5 mg/l and forty-nine (18.2%) took water above 2.6 mg/l. Among the 14-year-olds, two (0.74%) took water with fluoride levels between 0-0.5 mg/l, nine (3.35%) took water with fluoride between 0.6-0.8 mg/l, eight (2.97%) took water between 0.9-1.0mg/l, nine (3.35%) took water between 1.1-1.8 mg/l twelve (4.46%) took water between 1.9-2.5 mg/l while eighteen (6.69%) took water with fluoride levels above 2.6mg/l. For the 15-year-old, three (1.11%) used household water with a fluoride content of between 0-0.5 mg/l, four (1.49%) 0.6-0.8mg/l, two (0.74%); 0.9-1.0 mg/l. Also, two (0.74%) adolescents used water with a fluoride concentration of 1.1-1.8 mg/l, four (1.49%) had water between 1.9-2.5 mg/l and twelve (4.46%) had water fluoride content above 2.6 mg/l in the fifteen-year age bracket, table 3.3.

Table 3.3: The fluoride concentration in household water by age

Age in years	Number of children according to household water fluoride concentration in mg/l			
	0-1.0	1.1-2.0	≥2.1	Total
	n (%)	n (%)	n (%)	N (%)
13	77 (28.63)	30 (11.15)	77 (28.61)	184 (68.4)
14	19 (6.06)	9 (3.35)	30 (11.15)	58 (21.56)
15	9 (3.34)	2 (0.74)	16 (5.95)	27 (10.03)
Total n Percent	105 (38.03)	41 (14.13)	123 (29.37)	269 (100)

3.3.0: Prevalence and severity of dental fluorosis of adolescents living and learning in low fluoride (≤1.0mg/l), medium fluoride (≥1.1mg/l and ≤2.0mg/l) and high fluoride ≥2.1 mg/l areas in North Kajiado sub-county

3.3.1 Prevalence of dental fluorosis: One hundred and eighty-two (67.7%) of the adolescents had dental fluorosis while eighty-seven (32.3%) of them did not have dental fluorosis. Thirty-one (11.3%) males had no dental fluorosis while fifty-nine (21.3%) females did not have dental fluorosis, Figure 3.10.

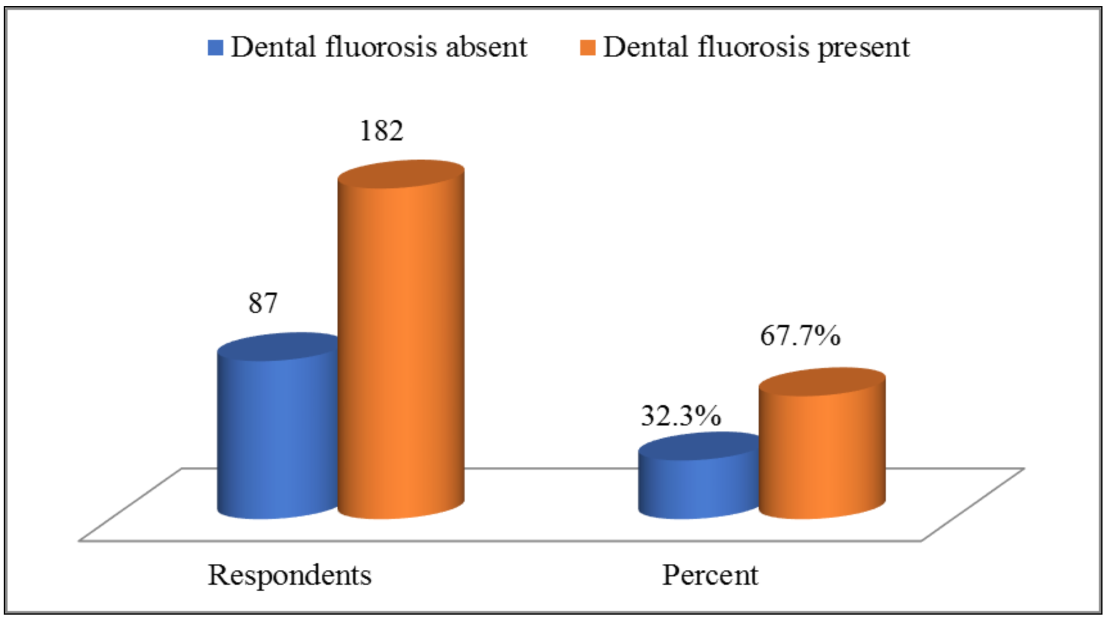

Figure 3.10: The participants affected by dental fluorosis and those with normal teeth

Sixty-three (22.8%) males had dental fluorosis while one hundred and twenty-three (44.6%) females had dental fluorosis.

The male population had a mean dental fluorosis of 0.6593, which was lower than the female population's mean dental fluorosis of 0.6854. A t-test was carried out to determine if there was any statistically significant difference in dental fluorosis between the adolescent male and the female populations.

However, an independent t-test with a Levine's equals assumed variance was non-significant with the independent t-test, $t\ (267) = -0.431$, $p = 0.667$ at 95% CL.

3.3.2 Prevalence of dental fluorosis by age: The prevalence of dental fluorosis was considered by age where sixty-one (22.68%) aged 13 years did not have dental fluorosis while one hundred and twenty-three (44.72%) had dental fluorosis. Among the 14-year-olds forty-three (16%) had dental fluorosis, while fifteen (5.58%) did not have dental fluorosis. At 15 years old, eleven (4.09%) of the study population who are this age did not have dental fluorosis while sixteen (5.95%) dental fluorosis figure 3.11.

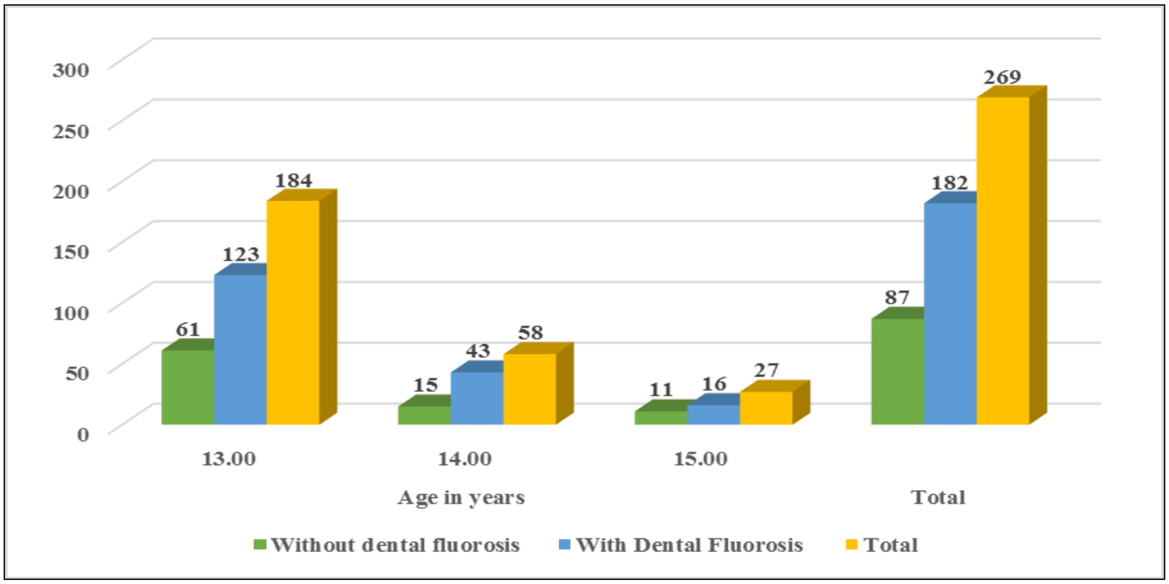

Figure 3.11: The distribution of dental fluorosis according to age

3.3.3. Predictive factors associated with the development of dental fluorosis

Several factors were considered to establish the best predictive factor(s) based on the linear regression analysis for the development of dental fluorosis. Some of these factors were a place of birth and duration of stay; the age at which the child lived in a high fluoride area the sender and the place of birth in north Kajiado up to the time of the study, the level of education of the parent/guardian/caregiver.

Also considered was the source of the water; the fluoride concentration in the water where the adolescent attended school and the fluoride concentration in the household water used for cooking and drinking. In this study household water with high fluoride content ≥2.6 mg /litre of fluoride was the most influential predictor factor with beta= 0.398, t=4.682, p≤0.001 at 95%CL. Also, dam /well water had a fluoride content which was a predictor but weaker than the household water whose fluoride content was high≥2.6 mg/litre while the well water had a fluoride content of 0.8mg/litre of fluoride, and the beta = 0.132, t=1.987, p= 0.048 at 95%CL. The other predictor variables were non-significant, table 3.4.

Table 3.4: A linear regression of multiple regressions of multiple regressors for the development of dental fluorosis

Variable	Standardised Coefficients Beta	t- value	Level of significance 95%
Age	-0.051	-00.783	0.434
Gender	0.047	0.750	0.454
Place of birth	-0.018	-0.249	0.803
Duration of residence in Kajiado sub-county	-0.116	-1.697	0.091
High Household Water Fluoride	0.398	4.682	0.001
Medium Household Water Fluoride	0.059	0.723	0.471
High School Water Fluoride	0.190	1.945	0.053
Medium School Water Fluoride	0.064	0.855	0.394
Borehole source	-0.013	-0.187	0.852
Dam/well source	0.132	1.987	0.048
River source	0.080	1.256	0.211
Other water sources	-0.032	-0.0505	0.614
Primary	-0.073	-0.414	0.679
High school	-0.143	-0.852	0.395
College	-0.130	-1.037	0.301
University	-0.048	-0.461	0.646

3.3.4 Prevalence of fluorosis with the water fluoride content in school areas: The presence or absence of dental fluorosis according to fluoride areas and forty (46%) of the adolescents without dental fluorosis were found in low fluoride areas. Twelve (13.8%) individuals were found in medium fluoride areas, while thirty-five (40.2%) of them were found in high fluoride areas. For those adolescents with dental fluorosis, twenty-eight (15.4%) of them were found in low fluoride areas, twenty-one (11.5%) of them were found in medium fluoride areas, while one hundred and thirty-three (73.1%) of them were found in high fluoride areas Figure 12. According to fluoride area, eighty-seven (32.2%) were without dental fluorosis while one hundred and eighty-two (69.5%) had dental fluorosis when an independent test was done Levene's test with equal variance assumed was significant with F=76.410, df=267, 130.3). p=0.000 at 95% CL. According to fluoride area, there was a significant difference in the prevalence of dental fluorosis with an independent samples test and a Levene's t-test for equality of means with F=14.253, DF= (267, 154.8), p=0.000, at 95% CL. However, the differences in the prevalence of fluorosis in the medium fluoride area were insignificant with F=1.085, df= (267, 157.9), p=0.610 at 95%CL. A Pearson's' Chi-square indicated significant associations between the prevalence and severity of dental fluorosis about the fluoride content in the water with a Chi-Square value = 35.156, d. f=6, p =≤ 0.0001 at 95% CL, figure 3.12.

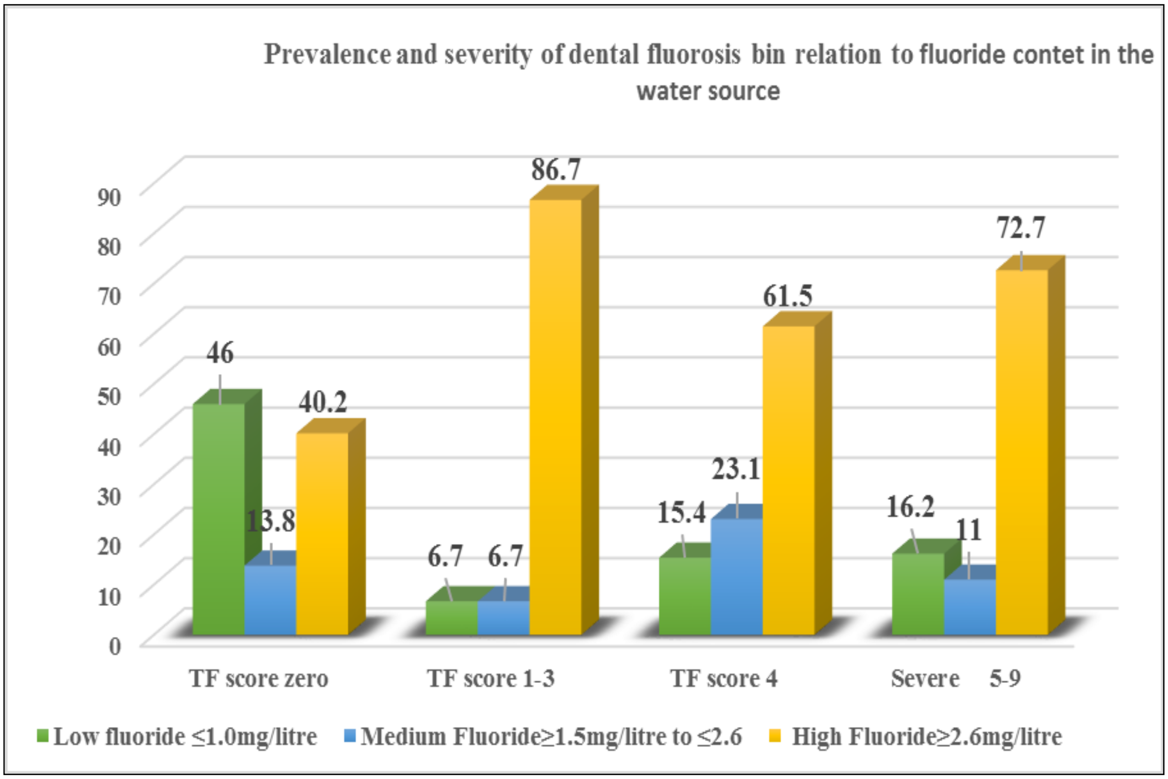

Figure 3.12: Presence or absence and severity of dental fluorosis according to fluoride areas

3.3.4 Household water fluoride content and the distribution of dental fluorosis:

Fifty-six (64.4%) of the adolescents without dental fluorosis was found in places that registered low household water fluoride, twenty-seven (31%) of them were found in places that registered medium household water fluoride, while four (4.6%) of them were found in areas that recorded high household water fluoride. There were forty-nine (26.9%) adolescents with dental fluorosis whose household water had low fluoride content. Fifty-four (29.7%) adolescents came from an area whose fluoride concentration in the household water was medium while seventy-nine (43.4%) came from an area where the analysed fluoride in the household water was high, Figure 3.13.

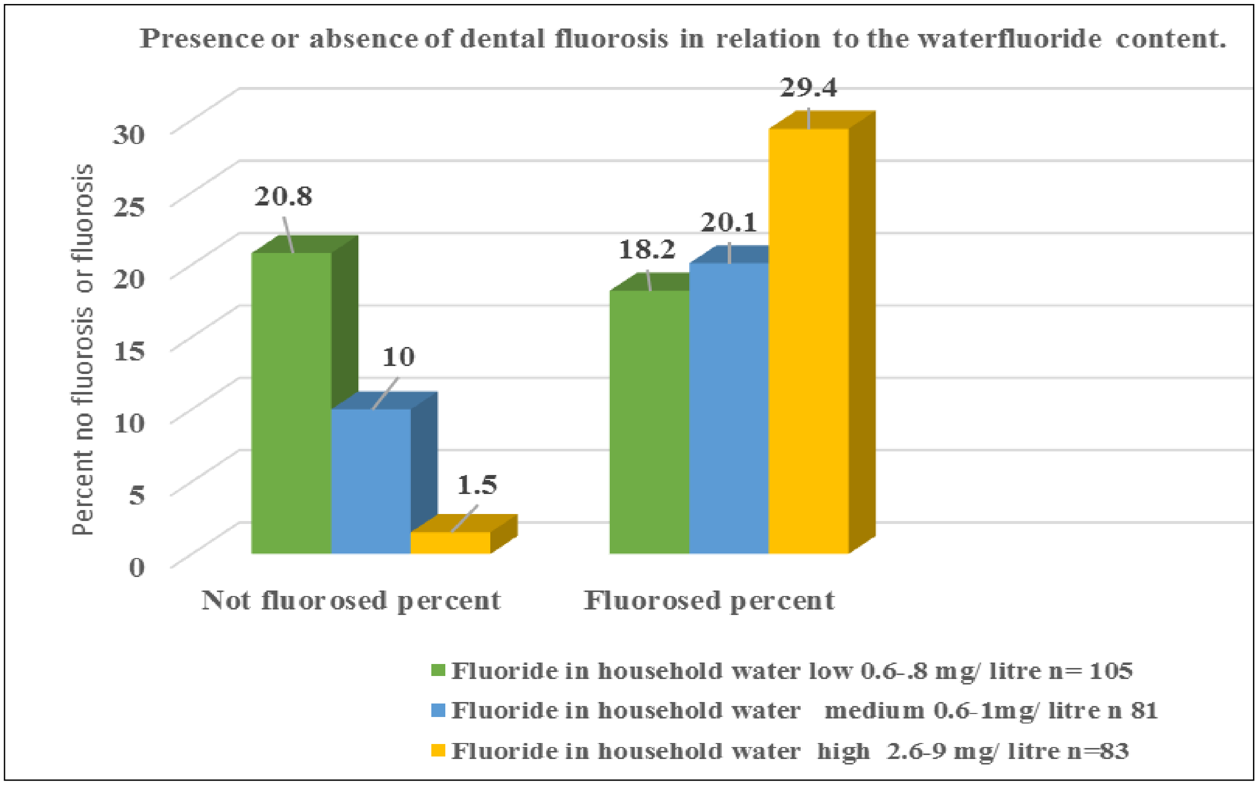

Figure 3.13: The presence and absence of dental fluorosis according to household water fluoride levels

The Chi-square of the association was done and the value for $X^2 = 49.913$, $p = 0.0001$ at 95% CL; which was a statistically significant association between household water fluoride content and presence of dental fluorosis. Hence, there is an association between the prevalence of dental fluorosis of adolescents living in low, medium and high levels of fluoride in household water.

3.3.5 Severity of dental fluorosis with the household water: The severity of dental fluorosis according to household fluoride categories. For those adolescents with normal teeth, fifty-six (64.4%) registered low household water fluoride, twenty-seven (31.0%) of them registered medium household water fluoride, while four (4.6%) registered high water fluoride. Those adolescents with dental fluorosis TF 1-3, four (26.7%) of them enrolled low household water fluoride, seven (46.7%) had average household water fluoride, while another four (26.7%) them had high household water fluoride. Those adolescents with fluorosis TF 4, eight (61.5%) of them registered low household water fluoride, four (30.8%) of them registered medium household water fluoride, while one (7.7%) of them were found to registered high household water fluoride. For those with dental fluorosis TF 5-9, thirty-seven (24.0%) of them lived in households which used low water fluoride, forty-three (27.9%) of the children were from households whose water had medium fluoride, and seventy-four (48.1%) were from homes with high water fluoride, figure 3.14.

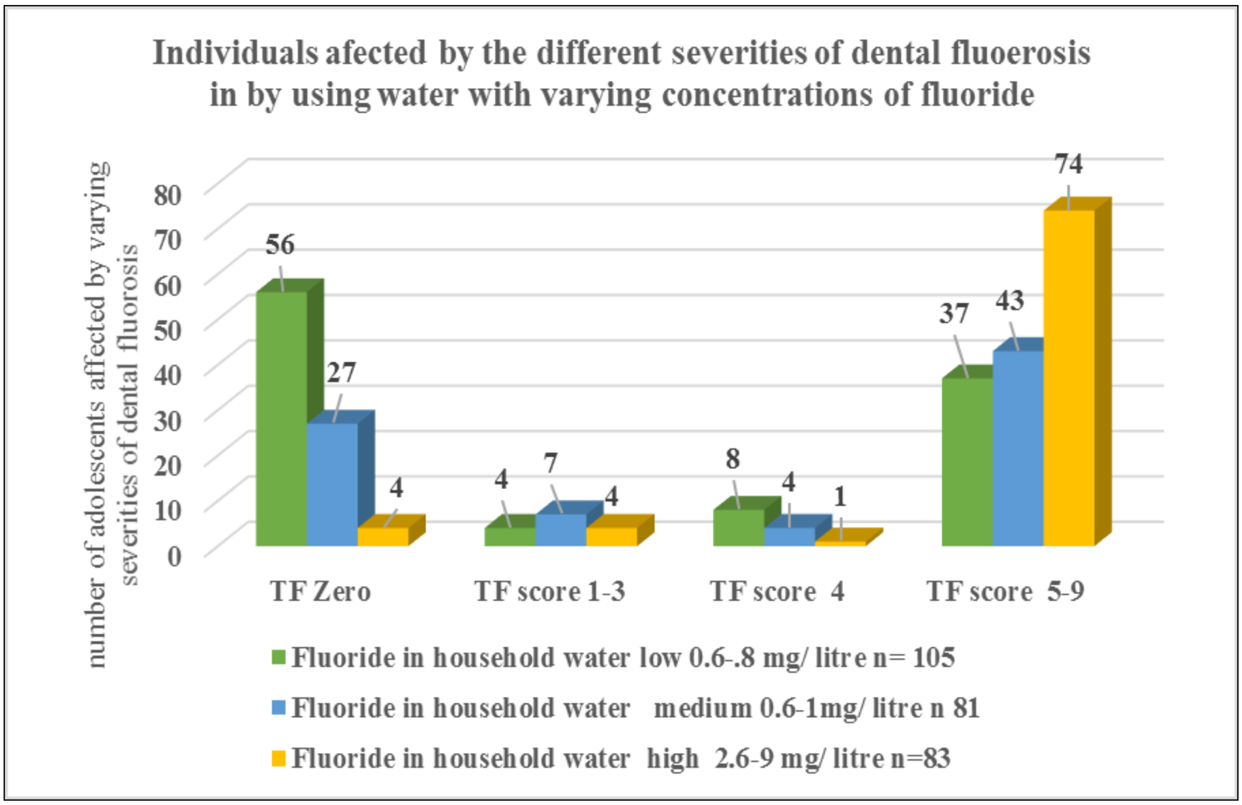

Figure 3.14: The distribution of severity of dental fluorosis according to household water fluoride content

The Pearson's chi-square test indicated a significant association between the household water fluoride and the prevalence of dental fluorosis with a Chi-square value =63.649, d. f=6, *p* =0.0001 at 95% CL.

3.3.6 Associations between Severity of dental fluorosis TF scores and fluoride in household water:

The different levels of severity of dental fluorosis for 269 individuals were correlated with the fluoride concentration in the household water which they use. A strong and negative association with the TF score zero -no fluorosis with where the Spearman's R_s=-0.403, p≤0.001 at 95% CL, while TF scores 1-3 had a weak and insignificant association with a coefficient $R_{s,}$ =0.038, p=0.536 at 95%CL. However, TF score 4 had a positive association with a coefficient $Rs_{=}$ 0.254, p≤0.001 at 95% CL and Score 5-9 also significant with a Spearman's R_s= 0.424, p≤0.001at 95% CL.

3.4 Social demographics and intellectual efficiency

3.4.0 Distribution of intellectual efficiency of adolescents 13-15 years of age

Intellectual abilities according to levels of intellectual efficiency were examined, and one (0.4%) individual was found to be intellectually challenged while thirty-four (12.6%) adolescents had below average score. One hundred and eighty-six (69.1%) of the study population had an average level of intellect. However, forty-five (16%) adolescent had an above-average intelligence, while three (1.1%) had a gifted level of intelligence figure 3.15.

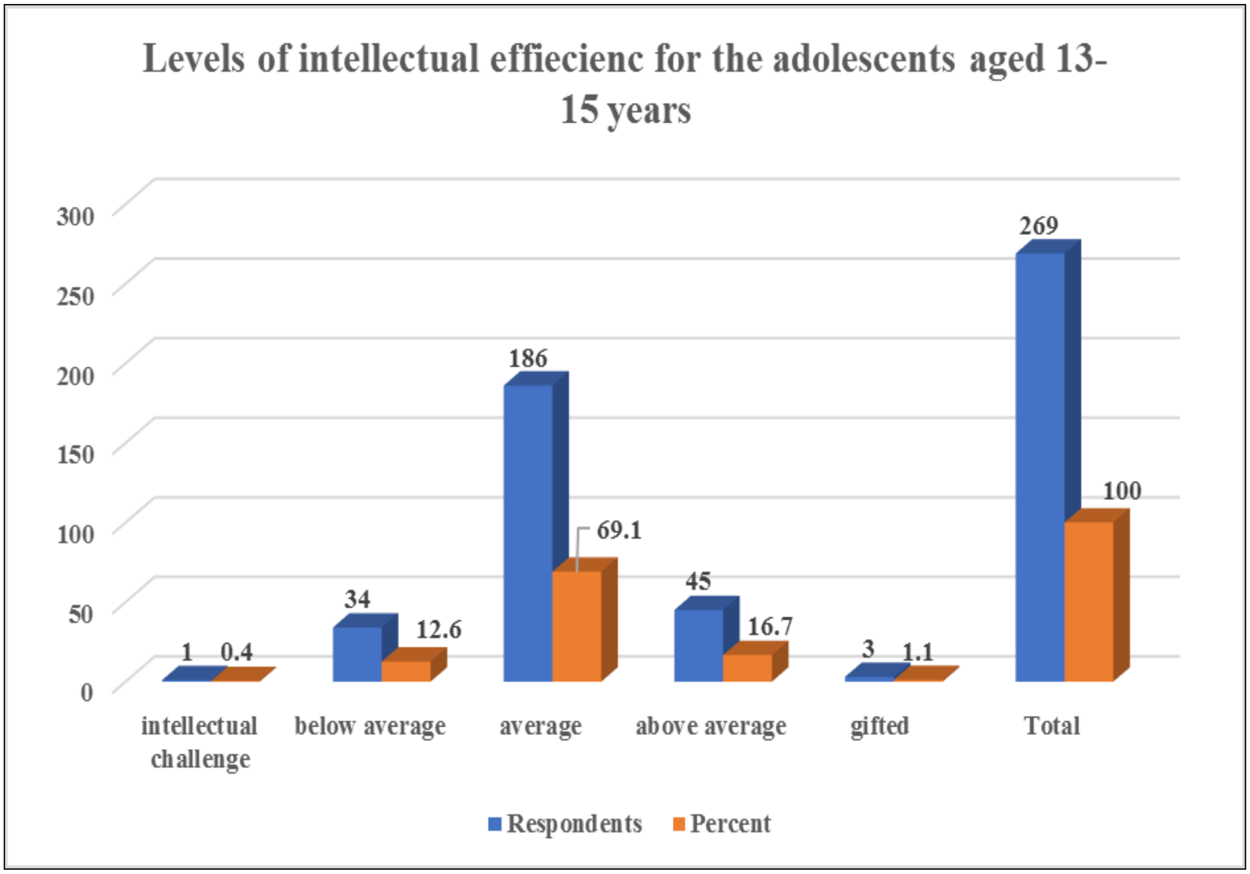

Figure 3.15: Distribution of intellectual efficiency for 269 individuals

3.5 Intellectual efficiency according to fluoride areas

3.5.0 Intellectual Efficiency (IE) and fluoride areas: The mean intellectual efficiency for the two hundred and sixty-nine adolescents in the study group was 100.6 ±13.7. The individuals from the low fluoride area were sixty-eight (25.28%) with a mean IE of 104.9±14.6, while those from the medium fluoride area were thirty-three (12.27%) with a mean IE of 106.3 ±13.6 and those from the high fluoride area were one hundred and sixty-eight (62.5%) they had the lowest mean IE of 97.8±2.50.

The intellectual efficiency of sixty-eight (25.28%) adolescents whose schools were in low fluoride areas was compared with the intellectual efficiency of two hundred and one (74.7%)

the individuals in the medium and low fluoride schools and the difference was significant with an independent samples test with a Levene's test for equality of variances where equal variance was assumed with F=1.816, df= (267, 105.474), p=0.003. Similarly, the intellectual efficiency of thirty-three (12.3%) individuals were compared with the intellectual efficiency of two hundred and thirty-six (87.7%) with a Levene's test for equality of variances where the equal variance was assumed with F=0.012, df= (267, 41.299), p= 0.013 at 95% CL. Also, the intellectual efficiency of one hundred and sixty-eight (62.5%) was compared with that of that of one hundred and one adolescents from the low and medium fluoride areas, and significant differences were noted with independent samples test with a Levene's test for equality of variances where equal variance was assumed with F= 2.731, df= (267, 189.705), p=0.000 at 95% CL.

3.5.1 Comparison of Levels of the intellectual efficiency with area fluoride concentration: There was one (0.4%) adolescent who was intellectually challenged from the high fluoride area. Five (1.9 %) adolescents from a low fluoride area were categorised as having an intellectual efficiency below average. There were three (1.1%) of the adolescents from the medium fluoride areas, while twenty-six (9.7%) were from high fluoride areas had an intellect below average. Hence, the majority of adolescents who were below average intellectual efficiency were from high fluoride areas. Those having an average intellectual efficiency were; forty-two (15.6%) from low fluoride areas, seventeen (6.3%), from medium fluoride areas and one hundred and twenty-seven (10%) from the high fluoride areas. For those adolescents who had an intellectual efficiency that was above average, nineteen (7.1%) were from the low fluoride areas, while twelve (26.7%) of them were from medium fluoride areas, and fourteen (5.2%) of them were from high fluoride areas. Gifted adolescents, two

(0.7%) of them were from low fluoride areas, one (0.4%) of them were from medium fluoride areas, while none of them was from a high fluoride area figure 3.16. The Pearson's Chi-square showed significant with a chi-square value =31.32, d. F=8, p = 0.001 at 95% CL.

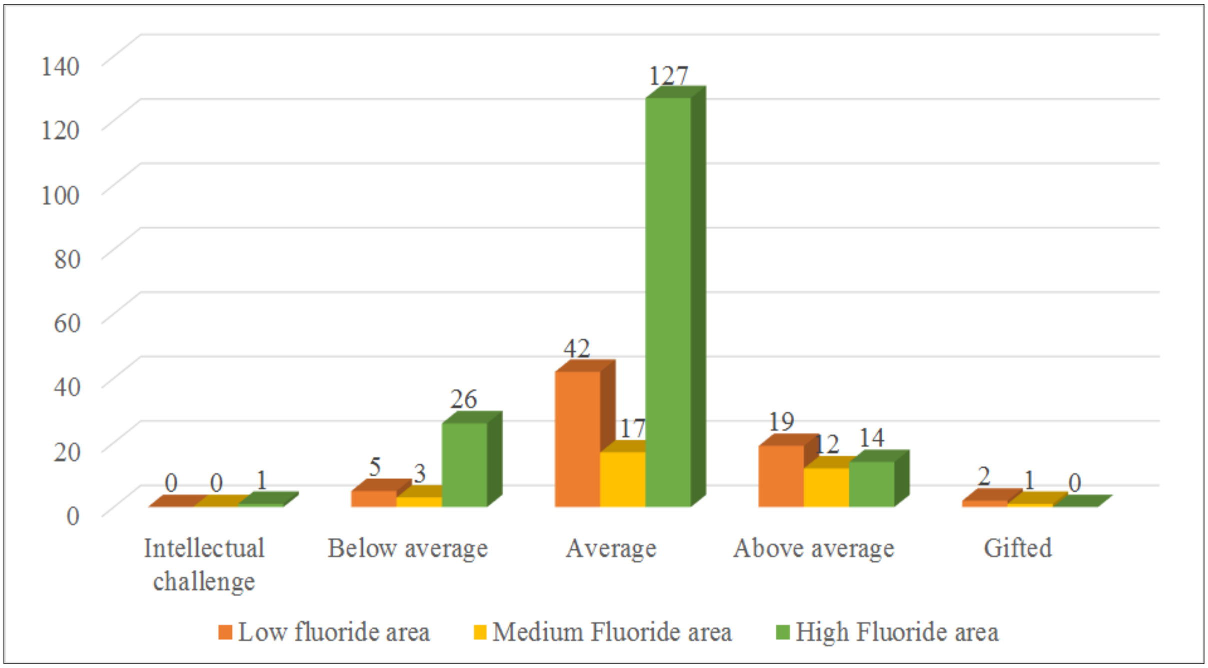

Figure 3.16: Intellectual efficiency with fluoride concentration in the school water

3.5.2 Comparison of Intellectual efficiency of adolescents of adolescents aged 13-15 years in North Kajiado Sub County and fluoride in area water:

The study group of two hundred and sixty-nine had a mean intelligence was 100.6±13.7 with a standard error of 0.8 (range 70-134). The adolescents using water with low fluoride (0 to 1.0mg/l) were sixty-eight (25.3%), and their mean intellectual efficiency was 104.9±14.6 with a standard error of 1.8 (range 71-134). Those who lived in medium fluoride (1.1mg/l to 2.0mg/l) area was thirty-three (12.3%), and they had a mean intellectual efficiency of 106.3±13.6 with a standard error of 2.4 (range 76-130). The individuals who were from the high fluoride of ≥2.1mg/l were one hundred and sixty-eight (62.5%) with a mean intellectual efficiency of 97.8±12.5 with a standard error of 1.0 (Range 70-134) figure 3.17.

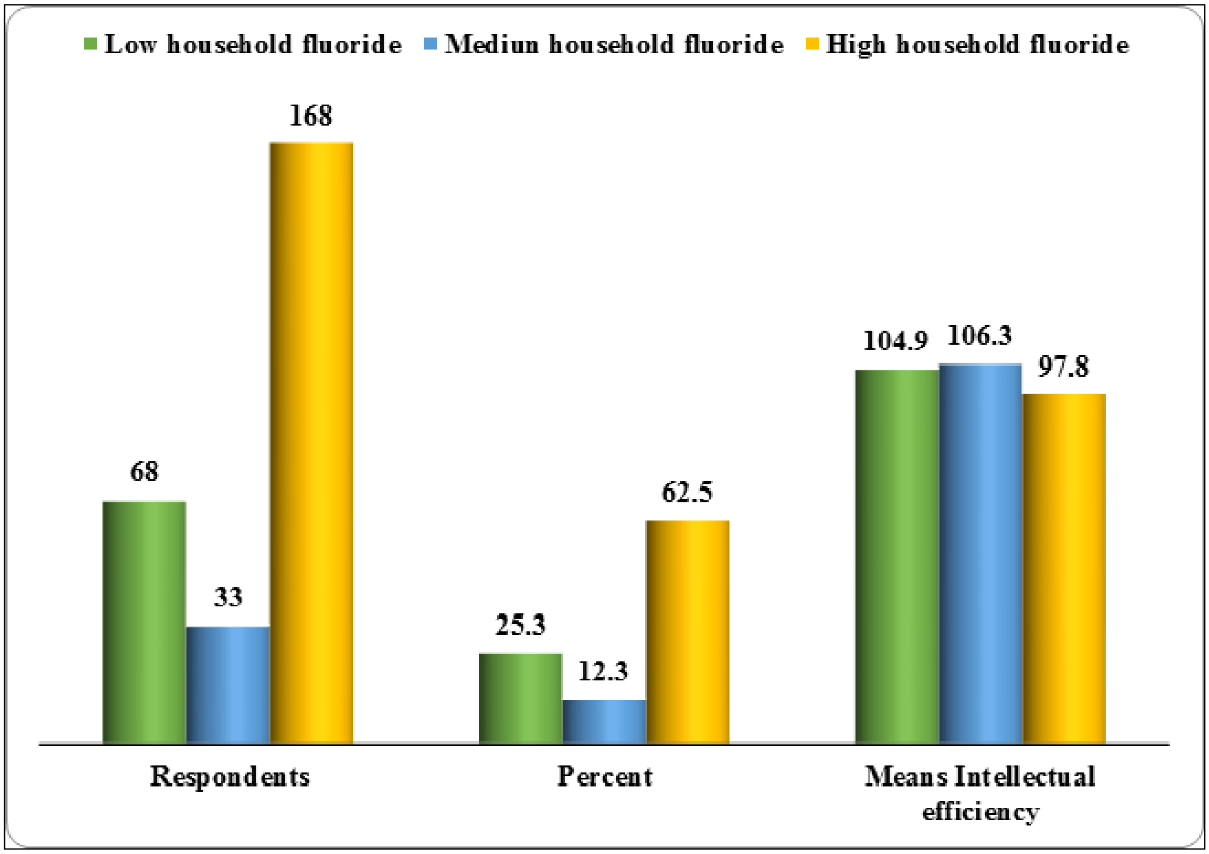

Figure 3.17: The mean intellectual efficiency with the area of fluoride concentration in the water

An ANOVA analysis showed their differences within and between groups for mean intellectual efficiency where F=10.613, df=2, ≤0.001 at 95%CL. A Tukey Post Hoc test was performed to establish the point of difference in the mean intellectual efficiency for individuals who lived and used water with low, medium and high fluoride concentrations, medium fluoride and high fluoride areas. Multiple comparisons were made for fluoride concentration with IE as the depended variable. There were differences in the mean IE for the children living in the low fluoride area and those living in the high fluoride area with a Post Hoc test Tukey, mean difference in intelligence -1.45098, p=0.862 at 95% CL.

A comparison of the intellectual efficiency of the children from the low fluoride area and the high fluoride (≥2.1mg/l) fluoride area showed that there were significant differences in the mean for intellectual efficiency with a Tukey Post Hoc test. The mean difference for intellectual efficiency was 7.13235, with a standard error1.89666, p≤0.001 at 95% CL. The intellectual efficiency of adolescents in the medium (≥1.1mg/l -2.0mg/ litre was compared with the intellectual efficiency of individuals living in a high fluoride (≥2.1mg/l-9mg/l) fluoride area and there was a mean significant difference with a Post Hoc test Tukey, where the mean difference was 8.58333, standard error =2.51263, p≤0.002 at 95% CL

Hence, the hypothesis that there was a difference in intellectual efficiency of adolescents within a low fluoride (≤1.0 mg/l) area, when compared to the intellectual efficiency of adolescents living in a high fluoride (≥2.0mg/l) fluoride area in North Kajiado Sub County is accepted with a Tukey post hoc test p=0.000 at 95 CL.

3.5.3 Comparison of IE and the fluoride content in household water:

The mean intellectual efficiency of two hundred and sixty-nine according to household water was 100.6±13.7. The households which had low fluoride in the household water had one hundred and five (39%), and their mean intellectual efficiency for was 107.5±13.0, while the households with medium fluoride in the household water had eighty-one (30.1%) and their mean intellectual efficiency was 96.2±12.4. The high fluoride in water households eighty-three (30.9%) individuals whose mean intellectual efficiency was 96.2±12.1, figure, 3.18

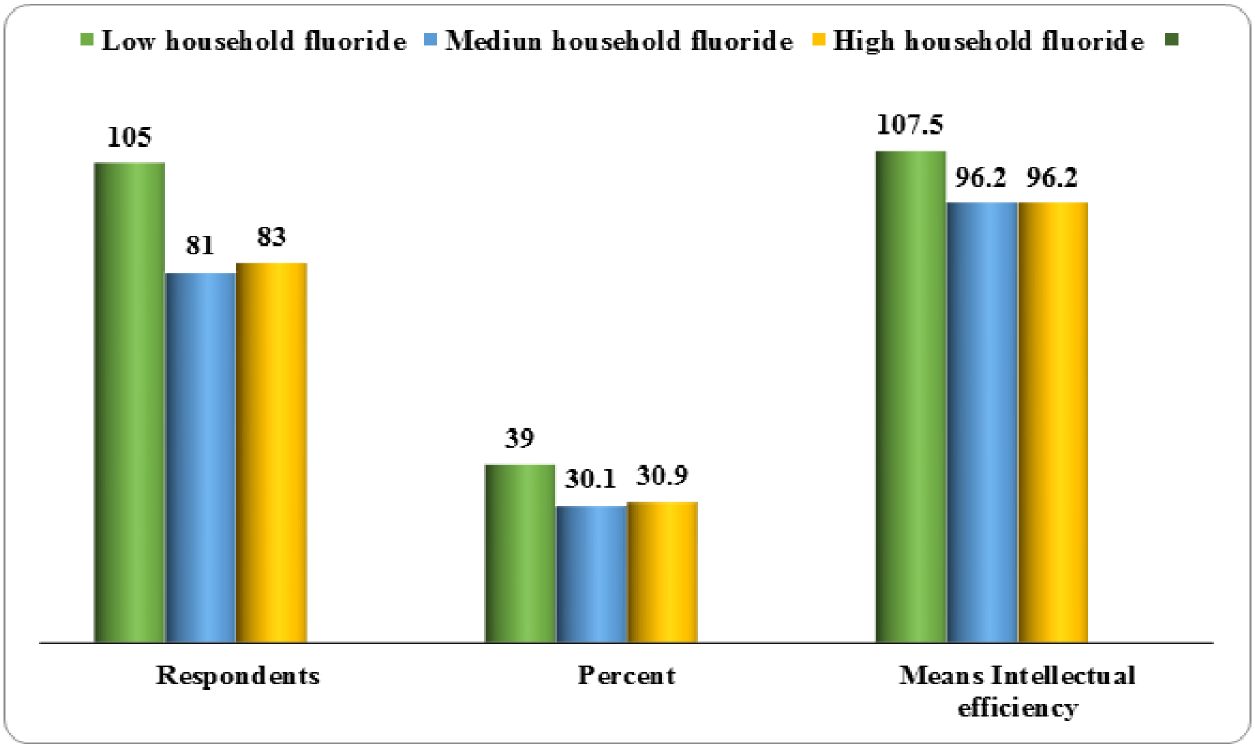

Figure 3.18: The distribution of IE according to the fluoride concentration of household water

: An analysis of household water for fluoride done and it was found that children who used water with low fluoride in were one hundred and five (39.03%). Out of whom with six (2.23%) being below average, sixty-two (23.05%) being average while thirty-four (12.64%) were above average and three (1.12%) were gifted. A total of eighty-one (30.11%) students ere exposed to medium fluoride, and one (0.37%) as intellectually challenged, fifteen (5.58%) were below average while fifty-eight (21.56%) were average and seven (2.60%) were above average. Out of the total of eighty-three (30.86%) with high household water fluoride, none was intellectually challenged or gifted, thirteen (4.83%) were below average, sixty-six (24.54%) were average, and four (1.49%) were above average, figure 3.19.

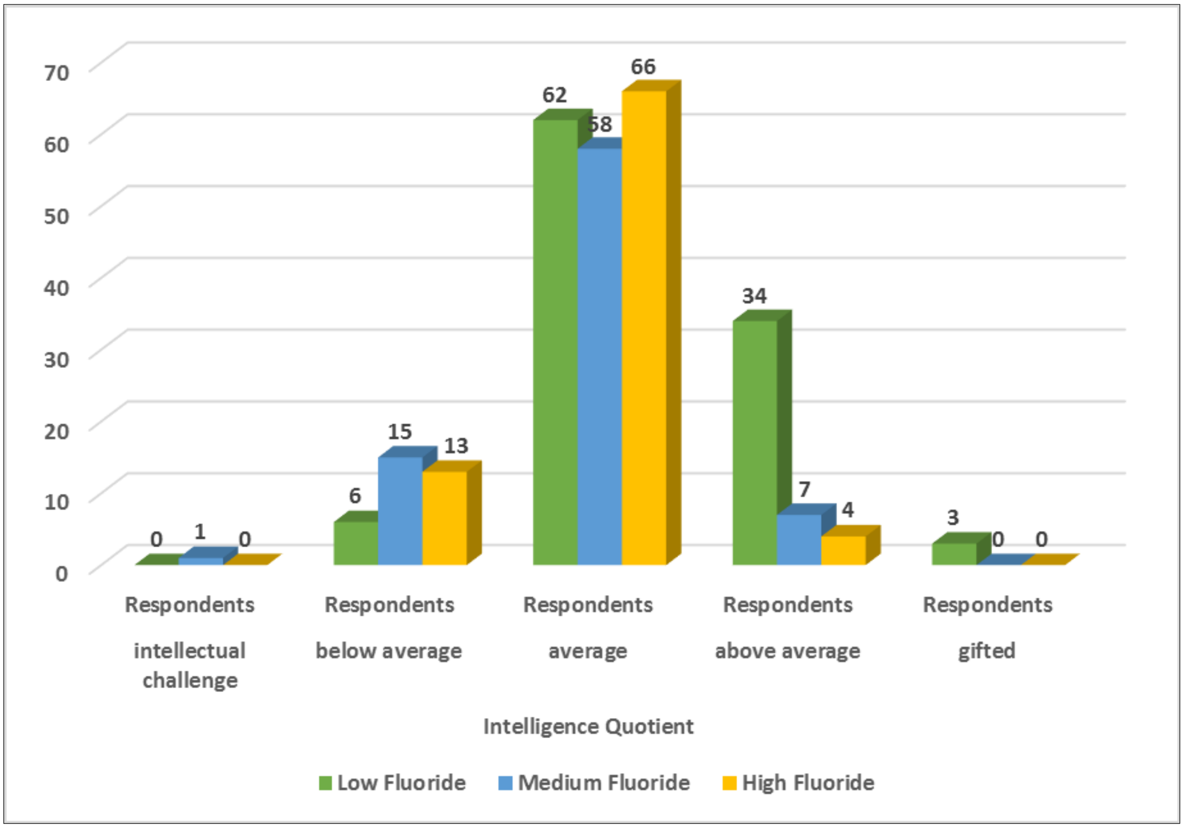

Figure 3.19: The distribution of intellectual quotient according to household water fluoride

3.5.4 Associations between intellectual efficiency and domestic water fluoride concentration: Intellectual efficiency when correlated with the varying concentrations in the household water it was found to have a weak and negative but significant association where R_S= -0.372, p=0.000 at 95% CL.

3.5.5 Intellectual efficiency (IE), levels of fluoride in household water, and relation to normal teeth and teeth with dental fluorosis:

The low fluoride concentration in household water and presence or absence of dental fluorosis, medium fluoride in household water with the presence or absence of dental fluorosis was considered. Also considered was high fluoride in household water concerning normal teeth and teeth with dental fluorosis.

Low fluoride without dental fluorosis had the highest mean Intellectual efficiency of 107.38 followed by medium household water fluoride with and without dental fluorosis at 96.27; high household water fluoride with dental fluorosis registered the lowest mean intelligence quotient of 95.90, figure 3.20.

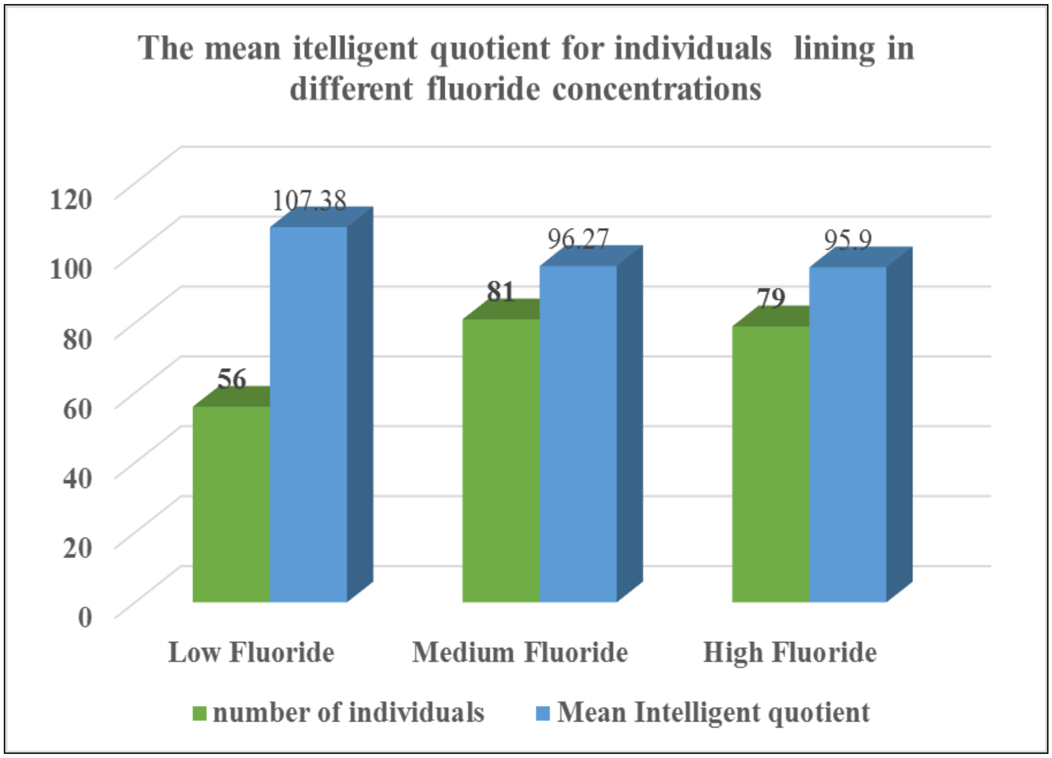

Figure 3.20: The mean intellectual efficiency of participants with low household water fluoride without dental fluorosis, medium household water fluoride with and without dental fluorosis and high household water fluoride with dental fluorosis

An ANOVA analysis showed significant differences in the mean differences with and between groups of variables with F=16.48, d. f=2.13, $p \leq 0.001$ at 95% CL. However, when a Tukey Post Hoc test was done it revealed the differences in the mean IE to be between low fluoride low and medium in the household water with a mean difference of 11.103, $p \leq 0.001$

at 95% CL. Similarly, a Tukey Post Hoc test was done, and it revealed differences in the mean IE between low fluoride low in the household water and high in the household water with a mean difference of 11.476, $p \leq 0.001$ at 95% CL. A Tukey between medium fluoride in the household water and the high fluoride in the household water was non -significant differences with a mean difference of 0.373, $p = 0.981$ at 95 %CL, table 3.5.

Table 3.5: Tukey Post hoc test showing the difference in efficiency living in low household water fluoride without dental fluorosis, medium household water fluoride with and without dental fluorosis and high household water fluoride with dental fluorosis

(I) Water Fluoride Categories (Household)	(J) Water Fluoride Categories (Household)	Mean Difference (I-J)	Std. Error	Level of significance at 95%	95% Confidence Interval	
					Lower Bound	Upper Bound
Low Fluoride	Medium Fluoride	11.103	2.202	0.000	5.91	16.30
	High Fluoride	-11.476	2.213	0.000	6.25	16.70
Medium Fluoride	Low Fluoride	-11.103	2.202	0.000	-16.30	-5.91
	High Fluoride	0.373	2.003	0.981	-4.36	5.10

The adolescents without dental fluorosis had a higher mean Intellectual Efficiency (103.87) than those with dental fluorosis (99.044). The independent t-test was performed, and a Levine's Test for equality of variances differences between Intellectual Efficiency and individuals with dental fluorosis and those without dental fluorosis was significant assuming equal variance with t (267) = 2.7745, p = 0.006, assuming the same difference.

3.5.6 Dental Fluorosis and Intellectual Efficiency:

The IE of the participants, according to the prevalence of dental fluorosis and fluoride content in the water was considered for low fluoride areas without dental fluorosis. The IE of the children who lived in the medium fluoride areas was compared with the IE of the children who were without dental fluorosis and those in the high fluoride areas with dental fluorosis. The mean IE for the group was100.8±13.6; however, in the low fluoride areas for children without dental fluorosis the mean for Intellectual efficiency was 106.38±15.1 followed by the children in the medium fluoride areas at 106.3±13.6; the individuals in the high fluoride areas registered the lowest mean Intellectual efficiency of 97.8±12.1, figure 3.21.

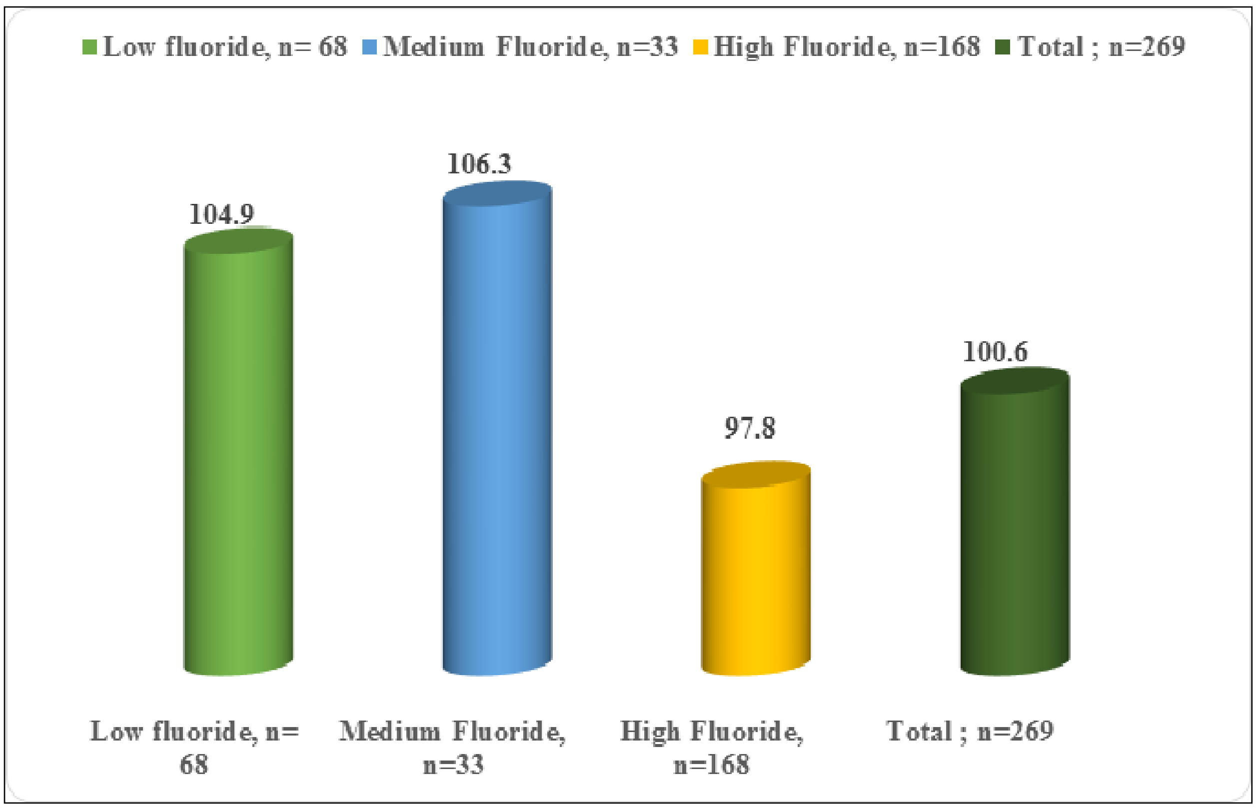

Figure 3.21: The means for Intellectual efficiency according to water fluoride areas

ANOVA test was performed to determine differences in the intellectual efficiency means for between and within groups, and it was observed that their significant differences between and within the groups with F =10.287, d. f= (2, 203), $p \leq 0.001$ at 95%CL. A Tukey Post Hoc test was done it revealed that there was a statistically significant difference in IE between low fluoride areas and high fluoride areas with a mean difference in IE of *8.593* with a standard error of 2.34 $p \leq 0.001$ at 95% CL. Also, there was a statistically significant difference in IE between medium fluoride areas and high fluoride areas, where $p \leq 0.002$.

A test Tukey post hoc analysis showed $p \leq 0.001$ in the IE of the adolescents in without dental fluorosis living in low fluoride low areas compared with the IE of the adolescents with varying degrees of dental fluorosis living in high fluoride. Also, the IE of adolescents without dental fluorosis from the school areas with medium fluoride concentration in the water was significantly different (Tukey, $p \leq 0.001$) from the IE of adolescents with dental fluorosis from the high fluoride. However, the IE of adolescents who used water with low and medium fluoride during the period of tooth development had no dental fluorosis, and the differences in their IE were insignificant. Hence the assumption that there are no differences in the IE of the adolescents who lived in low and medium fluoride areas using water with low and medium fluoride concentration was accepted, and the assumption that there was a difference is rejected. There were significant differences in between the IE of adolescents with normal teeth living in a low fluoride area when compared to the intellectual efficiency of adolescents aged 13-15 years residing in medium and high fluoride areas in North Kajiado sub-county.

3.5.7 Association of Intellectual efficiency and dental fluorosis according to gender

The distribution of level of intelligence according to gender in the presence and absence of dental fluorosis was considered. A total of ninety-four boys were examined out of whom sixty-three (67%) had dental fluorosis while thirty-one (33%) did not have dental fluorosis. The intellectually challenged formed one (1.1%) and this was the boy without dental fluorosis. Eighteen (19.15%) of the boys had intelligence levels that were below average out of whom twelve (12.77%) had dental fluorosis while six (6.38%) were without dental fluorosis. Fifty-six (59.57%) had an average level of intelligence with forty-one (43.6%) having dental fluorosis while fifteen (15.95%) among those with an average level of intelligence did not have dental fluorosis. Eighteen 19.15% had an above-average level of intelligence with nine (9.6%) having dental fluorosis while the other nine (9.6%) did not have dental fluorosis. Only one (1.1%) boy was gifted, and he had dental fluorosis. A total of one hundred and eighty-two girls were examined out of whom one hundred and twenty-three (67.58%) had dental fluorosis while fifty-nine (32.42%) did not have dental fluorosis. None was intellectually challenged. Sixteen (8.79%) of the girls had intelligence levels that were below average out of whom twelve (6.59%) had dental fluorosis while four (2.2%) were without dental fluorosis. One hundred and thirty-five (74.18%) had an average level of intelligence with ninety-nine having dental fluorosis while thirty-six among those with an average level of intelligence did not have dental fluorosis. Twenty-nine (15.93%) had an above-average level of intelligence with twelve having dental fluorosis while the other seventeen did not have dental fluorosis. Only two girls were gifted, and they did not have dental fluorosis figure 3.22.

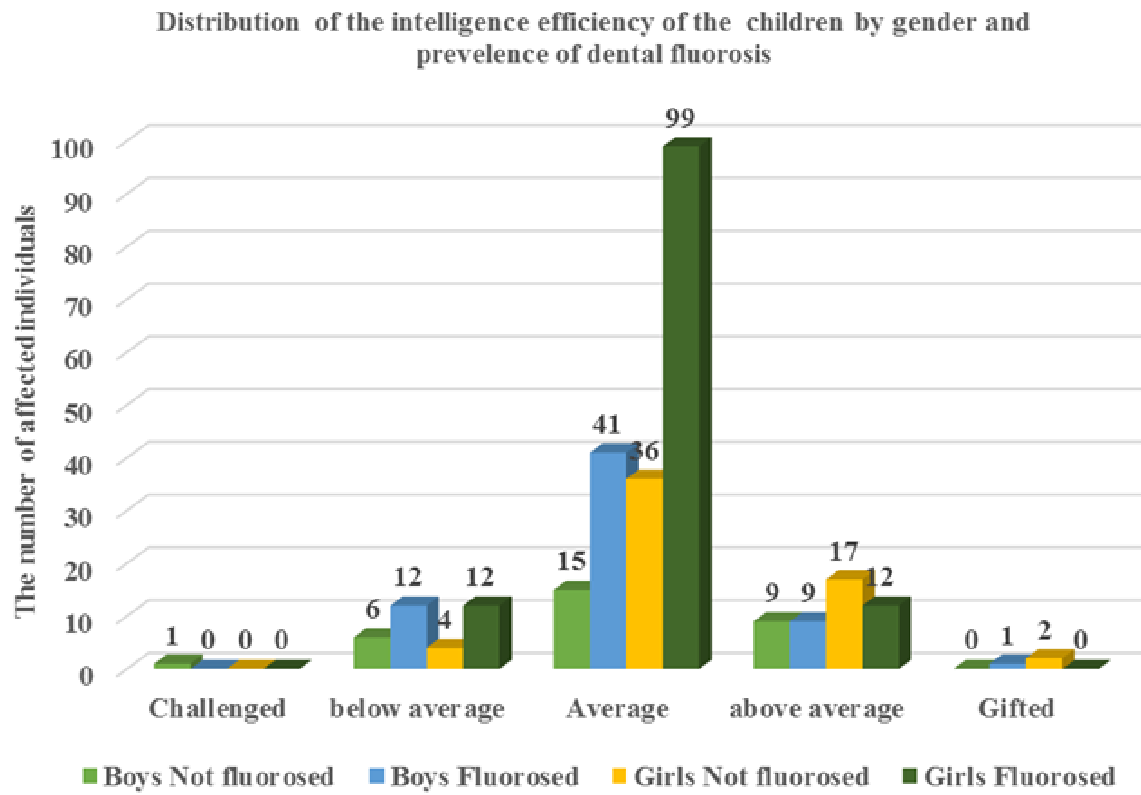

Figure 3.22: The distribution of intellectual efficiency by gender in children with and without dental fluorosis

3.5.8 Association between intellectual efficiency and severity of dental fluorosis: Also, the children who had dental fluorosis their intellectual efficiency correlated with the presence of dental fluorosis. The severity of dental fluorosis was categorised as normal TF score zero, TF scores 1-3, TF score 4 and TF score 5-9. It was noted that the children whose teeth had TF score zero their intellectual efficiency had a significant, positive but weak association with R_S=0.156, P=0.010, TF score 1-3 the association was also significant, but weak and negative with R_S=-0.136, p=0.026. However, the TF score had a nonsignificant, weak and negative association with R_S=-0.075, p=0.221. Similarly, the severe TF scores 5-9 were also nonsignificant although the association was weak and negative, with R_S=-0.043, p=0.485.

Therefore, the hypothesis that there is an association between varying degrees of severity of dental fluorosis and the intellectual efficiency of adolescents living in a low (≤1.0mg/l), medium (≥1.1mg/l and ≤2.0mg/l) and high fluoride ≥2.1mg/l areas in north Kajiado sub-county is accepted for TF scores zero, (normal teeth) and TF scores 1-3, with the respective r_s = r_s*=0.156, p=0.010 and* r_s*=-0.136, p=0.026. However, the hypothesis is rejected for TF scores 4 and TF scores 5-9 whose respective spearman's correlation coefficient was insignificant as* r_s*=-0.075, p=0.221 and* r_s*=-0.043, p=0.485.*

3.6.0 WORKING MEMORY

The working memory of adolescents living and learning in low fluoride (≤1.0mg/l), medium fluoride (≥1.1mg/l and ≤2.0mg/l) and high fluoride ≥2.1mg/l areas in North Kajiado sub-county.

3.6.1 Levels of Working Memory according to gender

The mean working memory for the Female population, 127.56±22.39, was higher than that of the male population, 119.91±24.6, figure 3.23.

An independent t-test was carried to determine whether there was a significant difference in working memory between the male, and the female populations were significant with an independent samples test and a Levene's test for equality of variances with equal variance not assumed where F=.960, df= (267, 267). p=.011at 95% CL.

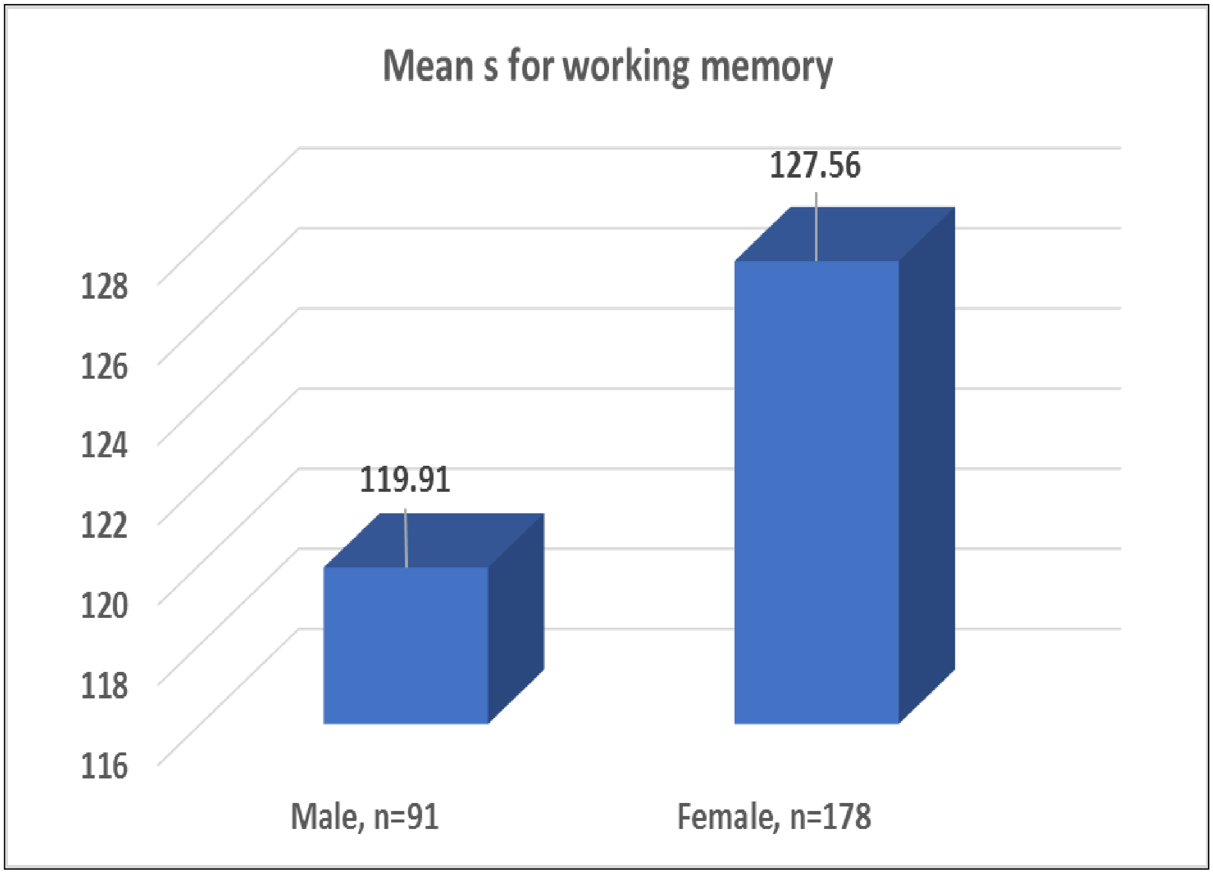

Figure 3.23: Mean working memory according to gender for the 269 adolescents

3.6.2 The distribution of levels of working memory by gender:

Out of the two hundred and sixty-nine children who were examined working memory fourteen (5.2%) were mentally challenged and out of the fourteen who were mentally challenged nine (3.4%) were boys and five (1.9%) were girls. Those who were below average were eleven (4.1%) out of two hundred and sixty-nine, and the males who were below average out of the eleven were three (1.2%) while the girls who were below average were eight (3%). The adolescents who had average working memory were thirty-three (12.3%) out of whom fifteen (5.6%) were boys, and eighteen (6.7%) were girls. The above average individuals were forty-three (16%) out of two hundred and sixty-nine, and the boys were fifteen (5.6%) while the girls were twenty-eight (10.4%), also the gifted were one hundred and sixty-eight (62.5%) out of whom forty-nine (18.2%) were boys, and the girls were one hundred and nineteen (44.2%), figure 3.24.

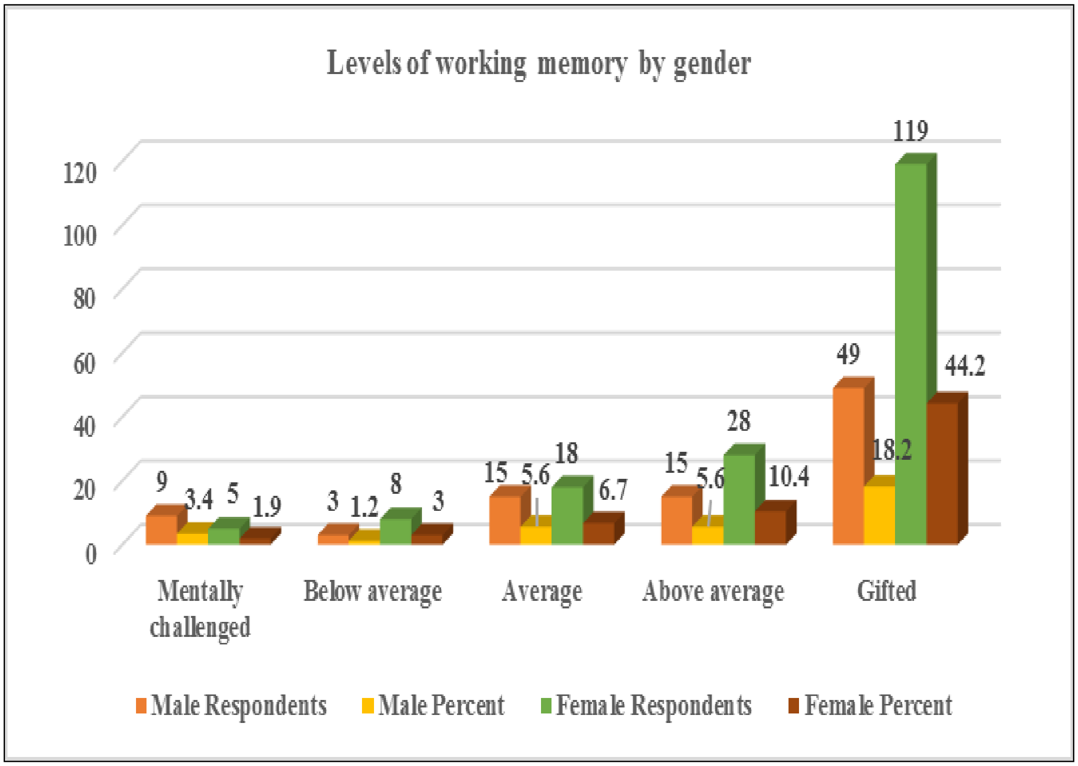

Figure 3.24: The distribution of the levels of working memory by gender

3.6.3 Working memory by age

Mean working memory by age group: The 13-year-olds were one hundred and eighty-four (68.4%) had a mean of 127.33±-21.833, standard. error 1.61, (range 62-155); fifty eighty (21.6%), 14-year olds had a mean of 120.91±25.875, standard error 3.398, (range 55-155), while twenty-seven (10%) 15-year-olds had a mean working memory of 117.63 ± 26.264, standard error 5.05 (range 65-155) figure 3.25.

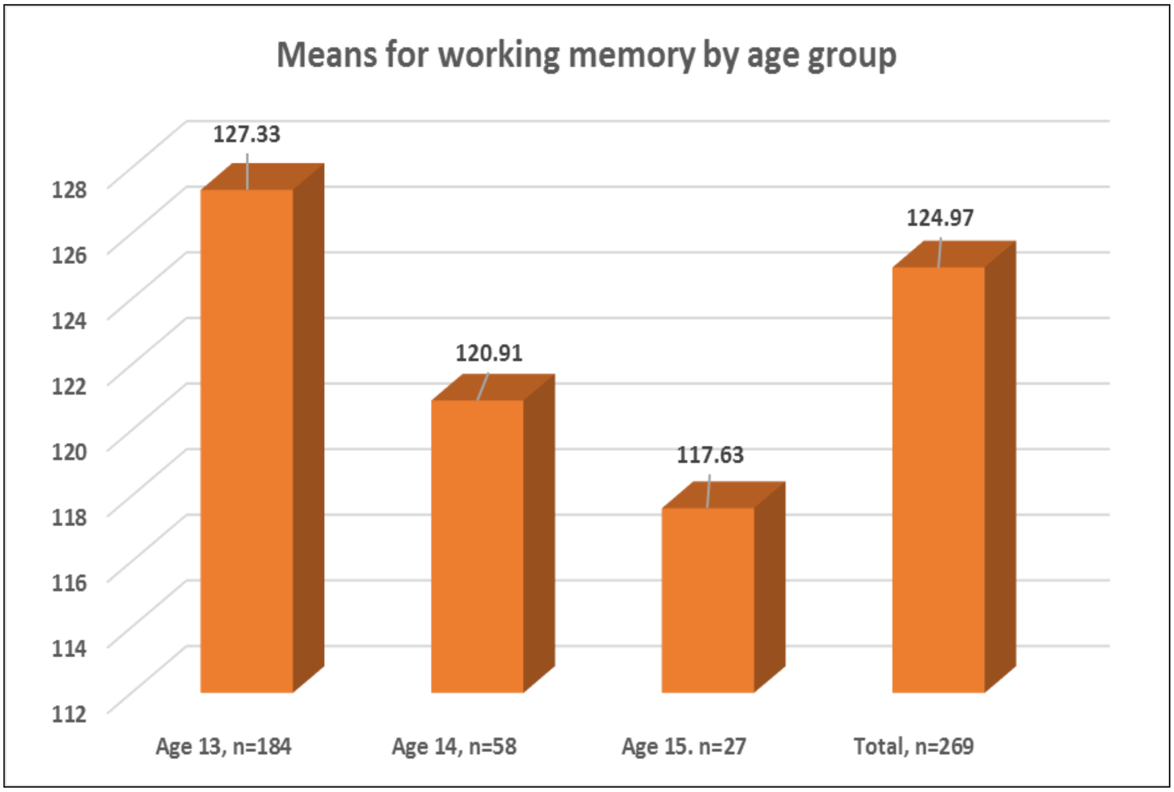

Figure 3.25: The mean working memory according to age

The ANOVA test suggests that there was a statistically significant difference in Working memory among the different age categories, F (2,256) =3.188. p=0.043 at 95%CL. A post hoc test had insignificant differences between ages 13 and 14; 13 and 15 also age 14 and 15 years, Table 3.6.

Table 3.6: Post hoc test for difference in working memory according to age

(I) Age	(J) Age	Mean Difference (I-J)	Std. Error	Level of significance nine %CL	95% Confidence Interval	
					Lower Bound	Upper Bound
13.00	14.00	6.418	3.496	.160	-1.82	14.66
	15.00	9.702	4.784	.107	-1.57	20.98
14.00	13.00	-6.418	3.496	.160	-14.66	1.82
	15.00	3.284	5.408	.816	-9.46	16.03
15.00	13.00	-9.702	4.784	.107	-20.98	1.57
	14.00	-3.284	5.408	.816	-16.03	9.46

3.6.4 Levels of mean working memory by age group: There were one hundred and eighty-four (68.40%) pupils aged 13-year olds who participated in the assessment for working memory. Six (2.23%) were found to be mentally challenged; six (2.23%) were below average, twenty-one (7.81%) were average, twenty-seven (10.04%) scored above average while one hundred and twenty-four (46.1%) were gifted. For the 14-year olds, a total of fifty-eight (21.56%) pupils participated. Four (1.49%) were mentally challenged, five (1.86%) scored below average, and eight (2.97%) scored average. Ten (3.72%) individuals were above average, and thirty-one (11.52%) were gifted. The 15-year olds twenty-seven (10.04%) pupils participated, four (1.49%) were found to be mentally challenged, four (1.49%) scored average while six (2.23%) scored above average, and thirteen (4.83%) were gifted figure 3.26.

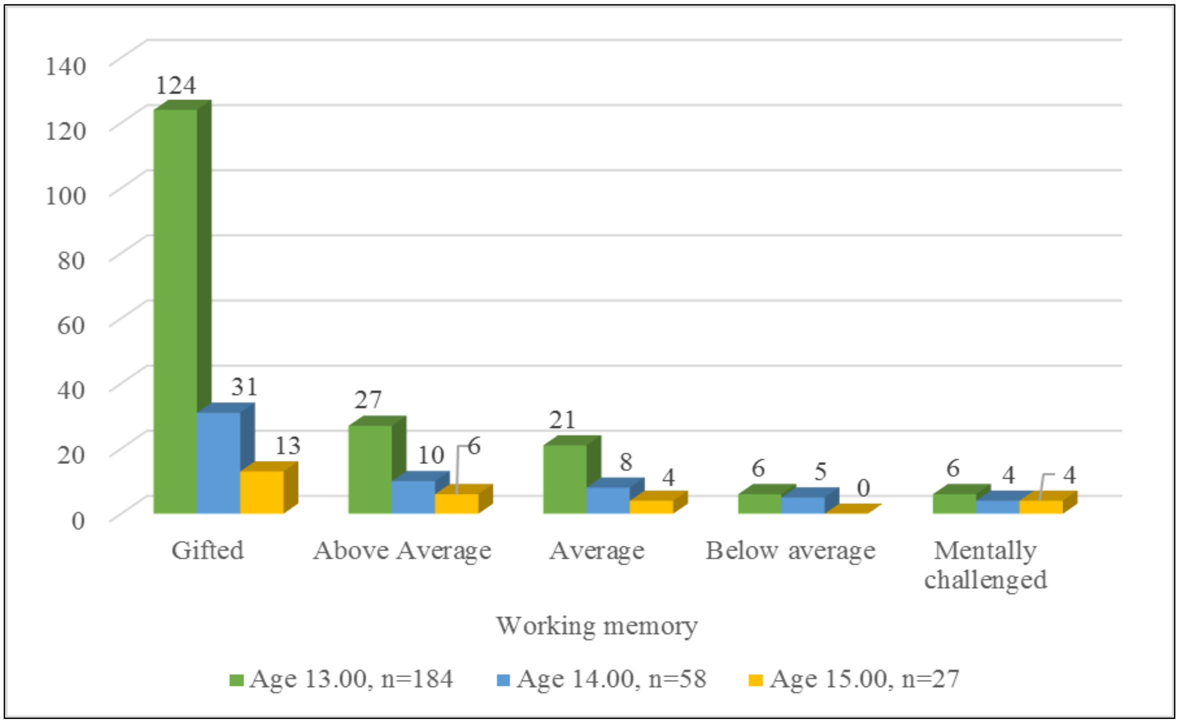

Figure 3.26: The distribution of working memory by age

3.6.5 Fluoride concentration in water and Working Memory:

3.6.5.1 Fluoride areas: The distribution of working memory, according to fluoride areas: The adolescents from low water fluoride areas were sixty-eight (25.28%). Thirty-three (12.27%) were from medium fluoride areas while one hundred and sixty-eight (62.45%) were from high fluoride areas. There were forty-five (16.73%) gifted children from the low fluoride areas; fourteen (5.2%) were above average three (1.11%) were average, three (1.11%) scored below average while three (1.11%) were mentally challenged category. From the medium fluoride areas, twenty-seven (10.03%) were gifted, three (1.11%) were above average, and three (1.11%) were average. None scored below average and mentally challenged from the medium fluoride areas. Ninety-six (35.69%) gifted children were from the high fluoride area; 26 (9.67%) were above average, 27 (10.03%) were average, eight

(2.97%) were below average while eleven (4.09%) scored in the mentally challenged category, figure 3.27.

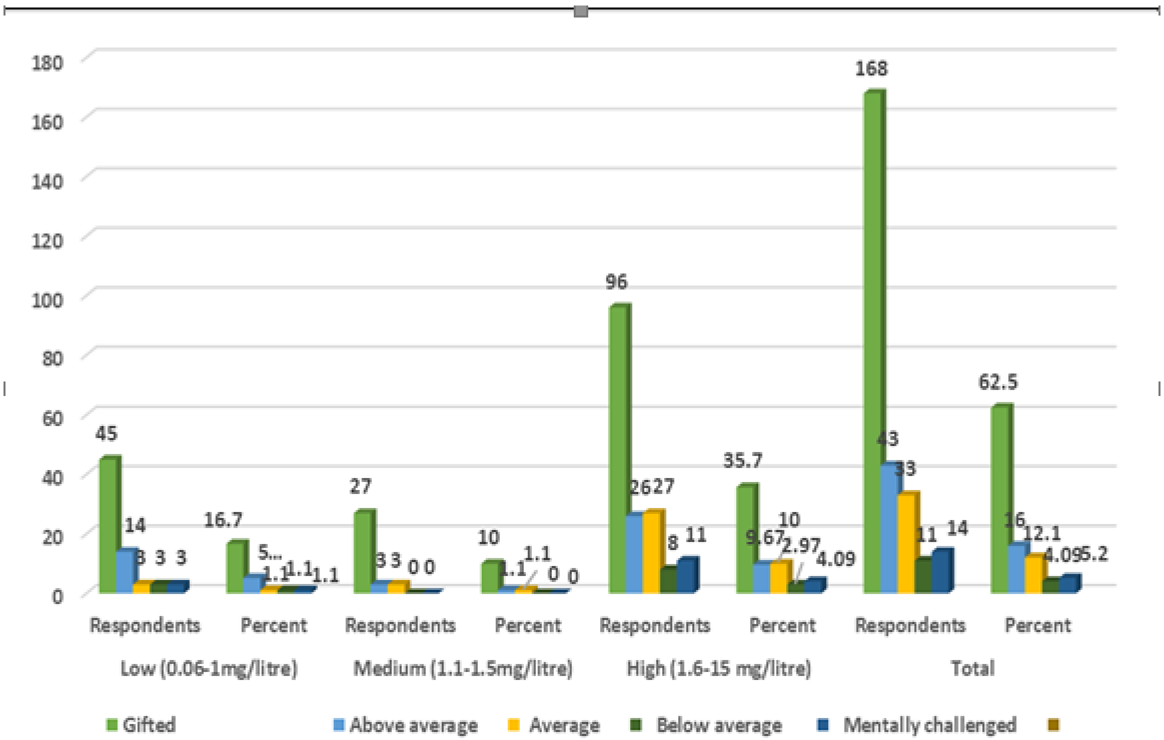

Figure 3.27: Distribution of working memory according to fluoride areas

An ANOVA test for comparison of the means for between and within groups for working memory was done and it showered significant differences in the means for the low, medium and high fluoride areas with F= 6.319, df=(2, 266), p=0.002 at 95% CL. However, a Tukey Post hoc test for multiple comparisons showered the significant difference between the means for working memory for the adolescents from the low and the medium fluoride area with a mean difference in the working memory (M=12.289 SE=4.869), p=0.033 at 95%CL. Similarly, the differences in the means for working memory for the children in the medium and high fluoride areas was significantly different with a difference in the means (M=-15.509

SE=4.37), p=0.001 at 95% CL. However, the comparison in the means for working memory between the children in the low and high fluoride areas was insignificant with mean difference (M=-3.220, SE=3.299) p=0.593.

3.6.5.2 Distribution of Working Memory of children using Low, Medium and High fluoride in household water:

Low household fluoride had the highest mean working memory of 134.45±16.16 while the IE of the children using household water with high fluoride, had WM of 122.06±24.77, and medium household fluoride registered the lowest mean working memory, 117.00±25.88 figure 3.28.

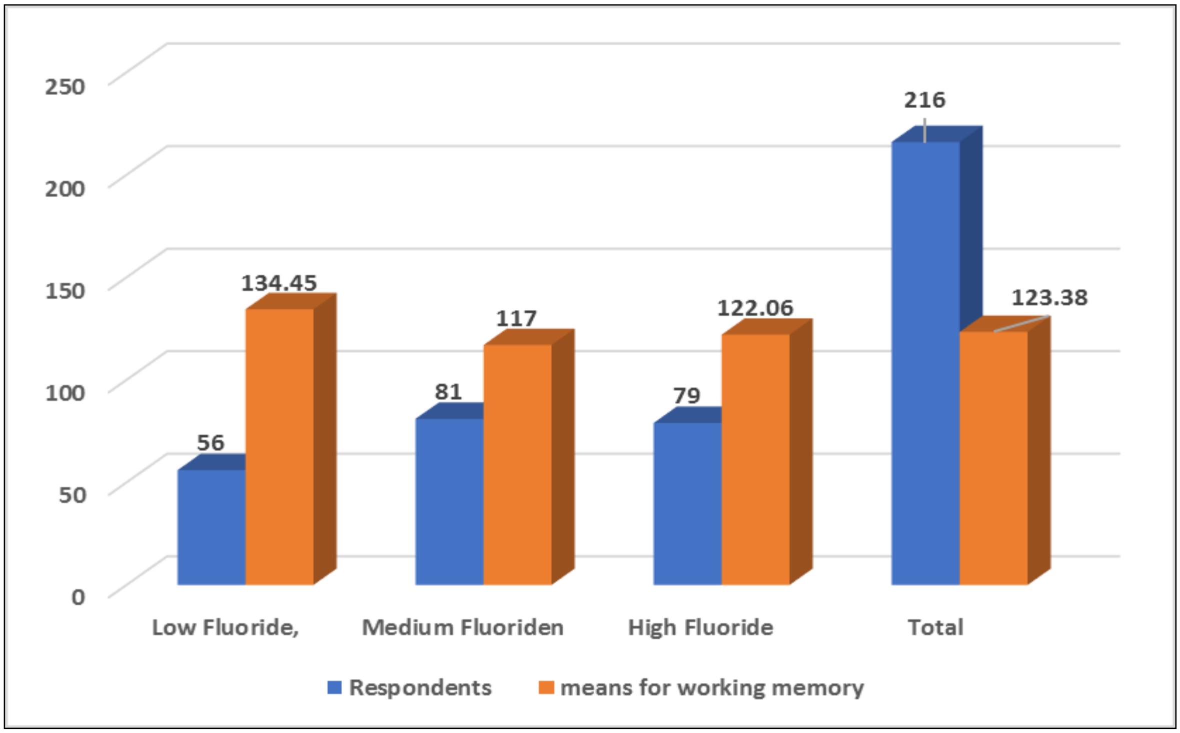

Figure 3.28: The working memory scores comparisons of means in low, medium and high fluoride

Significant differences working memory of children using low, medium and high fluoride in household water fluoride ANOVA F =9.473, df= (2,213) p=.000)

A turkey posts hoc test was then carried out, and it revealed that there was a statistically significant difference in working memory between low household fluoride and high household fluoride, p=0.007, there was also a statistically significant difference in working memory between low household fluoride and medium household fluoride, p =0.000. There was no statistically significant difference in working memory between children using water with medium fluoride concentration and high fluoride concentrations, p=0.356 at 95% CL, Table, 3.7.

Table 3.7: A Tukey Post hoc test for the working memory of children using varying fluoride concentration in the household water.

(I) Water Fluoride Categories (Household)	(J) Water Fluoride levels of fluoride in household water fluoride in water	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Low Fluoride	Medium Fluoride	17.446*	4.051	.000	7.89	27.01
	High Fluoride	12.383*	4.072	.007	2.77	21.99
Medium Fluoride	Low Fluoride	-17.446*	4.051	.000	-27.01	-7.89
	High Fluoride	-5.063	3.686	.356	-13.76	3.64
High Fluoride	Low Fluoride	-12.383*	4.072	.007	-21.99	-2.77
	Medium Fluoride	5.063	3.686	.356	-3.64	13.76

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

There were fifty-nine (21.93%) individuals who used water with a low fluoride content had gifted working memory, fifteen (5.58%) had above average, nineteen (7.06%) had average working memory, and below-average WM there were four(1.4%), and eight (2.97%) were mentally challenged. A total of eighty-one (30.11%) participants had used household water with medium fluoride content, and forty-three (15.99%) had gifted working memory, eighteen (6.69%) had an above-average working memory. Ten (3.72%) from the medium fluoride in water had an average working memory, while four (1.49%) had a below-average working memory, and six (2.23%) were mentally challenged. There were eighty-three (30.9%) individuals whose household water fluoride was high among whom sixty-six (24.54%) were gifted, forty-three (15.99%) had above average working memory, and thirty-three (12.27%) had an average working memory. Eleven (4.09%) had a below-average working memory, and fourteen (5.20%) had a working memory categorised as mentally challenged, figure 3.29.

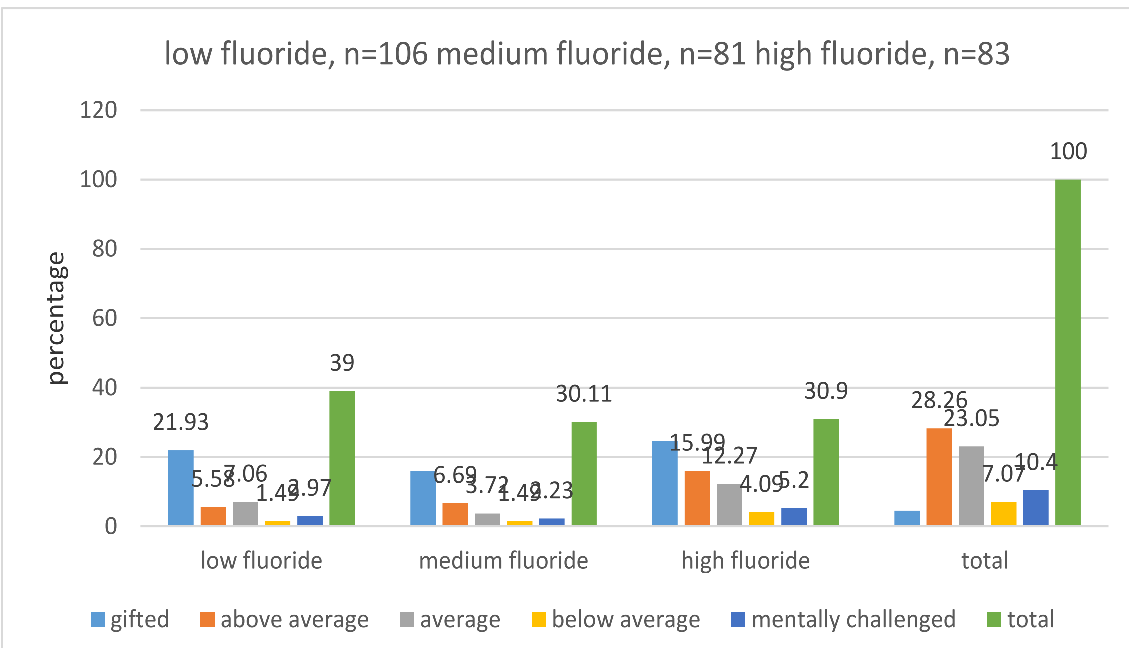

Figure 5.29: The distribution of working memory according to household water fluoride

Levels of working memory: The varying fluoride concentrations in the household water categorised as low, medium and high used as the selection variable the children were distributed according to the working memory as 11 (4.1%) low average, 33(12.3%) were average; 43 (16%) were high average and 43 (16%) very high average and 125 (46.5%) as extremely high. A Kruskal Wallis test for multiple non-parametric comparisons was made, and it indicated insignificant differences in the working memory of the children using varying concentrations in household water with a Kruskal Wallis Chi-square=8.211, df=4, p=0.084

The ANOVA analysis indicated a significant difference between groups of adolescents with low household fluoride, medium household fluoride and high household fluoride in Kajiado North sub-county concerning Intellectual efficiency as determined by the one-way ANOVA (*F (2,266) =11.815, p=.000).* A turkey posts hoc test was then carried out, and it revealed that there was a statistically significant difference in working memory between low household fluoride and high household fluoride, p=0.008, there was also a statistically significant difference in working memory between low household fluoride and medium household fluoride, p =0.000. There was no statistically significant difference in working memory between medium fluoride concentrations in household water and high fluoride, where p=0.222, Table 3.8.

Table 3.8: Turkey HSD test for working memory of adolescents with the fluoride concentration in the water used by the households

(I) Water Fluoride Categories (Household)	(J) Water Fluoride Categories (Household)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Low Fluoride	Medium Fluoride	15.810*	3.329	.000	7.96	23.66
	High Fluoride	9.966*	3.306	.008	2.17	17.76
Medium Fluoride	Low Fluoride	-15.810*	3.329	.000	-23.66	-7.96
	High Fluoride	-5.843	3.516	.222	-14.13	2.44
High Fluoride	Low Fluoride	-9.966*	3.306	.008	-17.76	-2.17
	Medium Fluoride	5.843	3.516	.222	-2.44	14.13

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

3.6.5 Working memory and severity of dental fluorosis:

The chi-square of the association carried out, χ (8) = 14.409, DF=8, p = .072 Suggests that there is no statistically significant association between fluoride areas and working memory. The WM of the adolescents who attended schools in environs with medium fluoride concentrations in the water had the highest mean working memory of 133.06, followed by low fluoride areas, 125.60, and areas with high fluoride areas registered the lowest mean working memory, 123.13, figure 3.30.

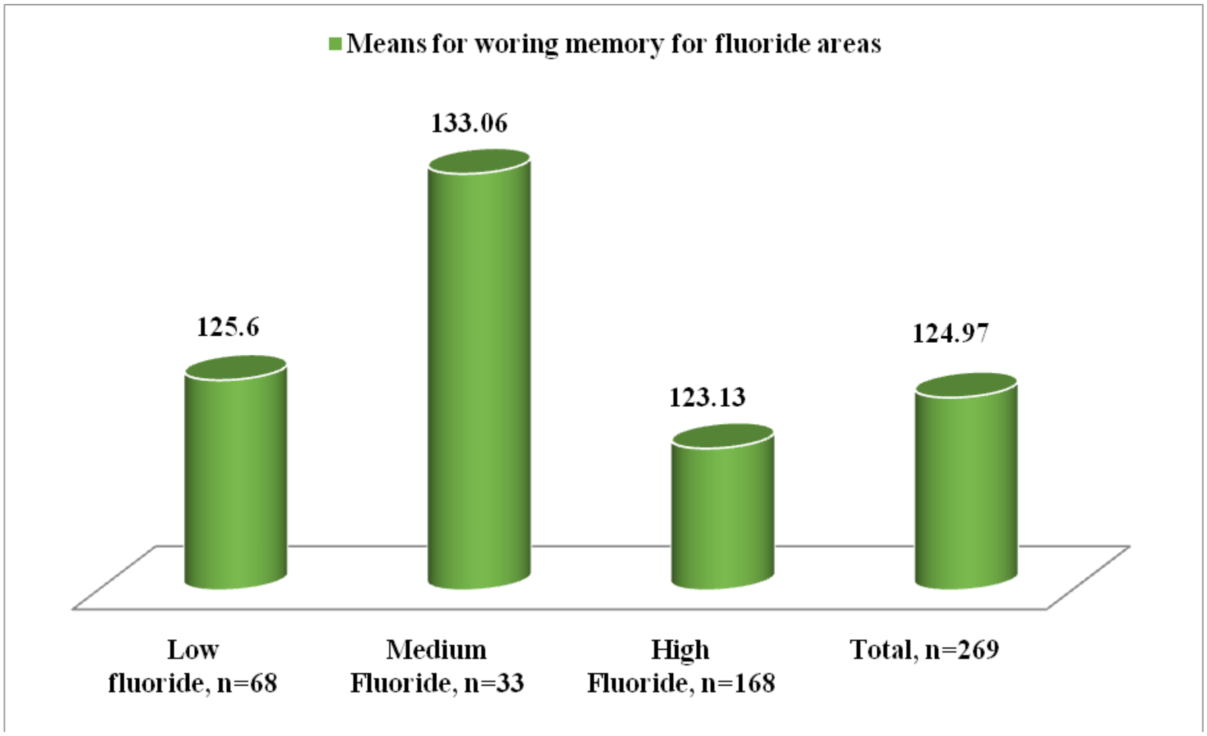

Figure 3.30: Average working memory according to fluoride areas

The ANOVA test suggests that there was no statistically significant difference between the groups in (*F (2,266) =2.545, p=.080).*

3.6.5 Comparison of working memory and prevalence of dental fluorosis: Working memory of adolescents aged 13-15 years living within a low (≤1.0mg/l) fluoride area, and did not have dental fluorosis was compared to the working memory of those without dental fluorosis medium fluoride (≥1.1mg/l and ≤2.0mg/l). Also, the working memory of the adolescents aged 13-15years living in a low (≤1.0mg/l) fluoride area with normal teeth was compared to the working memory of those with dental fluorosis living in a high fluoride ≥2.1mg/l areas in North Kajiado sub-county. The medium fluoride areas had the highest mean working memory of 132.66, followed by low fluoride areas, 129.35, and areas with high fluoride areas registered the lowest mean working memory, 126.18 figure 3.31.

The ANOVA showed insignificant difference between groups regarding working memory of adolescents with normal teeth in a low (≤1.0mg/l) fluoride area when compared to the working memory of those living in a medium (≥1.0≤2.0mg/l) with and without dental fluorosis also those from high fluoride (≥2.1mg/l) with dental fluorosis in North Kajiado sub-county, determined by one-way ANOVA (*F(2,202)=2.764, p=0.065)*

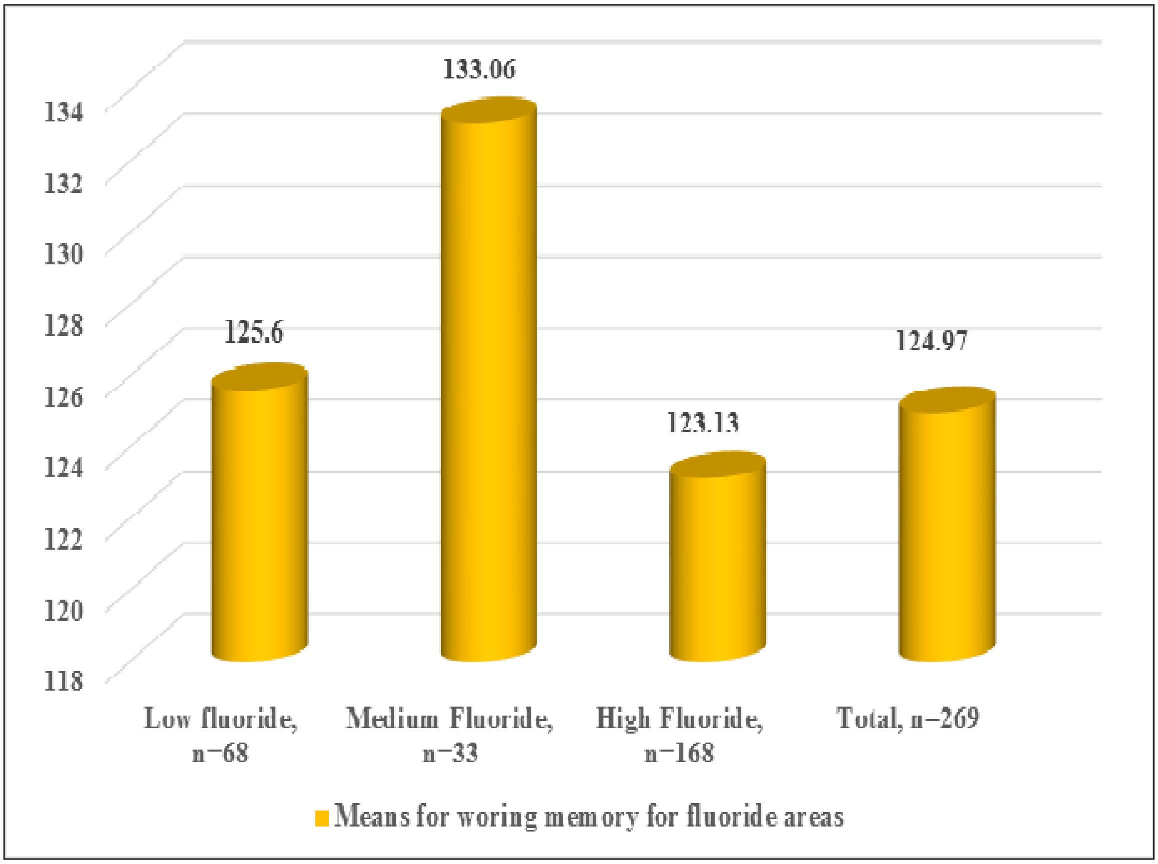

Figure 3.31: Mean working memory in participants in low fluoride areas without dental fluorosis, medium fluoride with and without dental fluorosis and high fluoride areas with dental fluorosis

3.6.5.1 Working memory with normal and fluorosed teeth:

The working memory scores in the presence or absence of dental fluorosis was also considered, and five (1.86%) participants without dental fluorosis were dentally challenged while nine (3.35%) with dental fluorosis were mentally challenged. A total of eleven (4.09%) had a below-average working memory, and they all had dental fluorosis while thirty-three (12.27%) had an average working memory with nine (3.35%) did not have dental fluorosis while twenty-four (8.92%) had dental fluorosis. Of the forty-three who had an above-average working memory, fourteen (5.20%) did not have dental fluorosis while twenty-nine (10.78%) had dental fluorosis. For the gifted ones who were one hundred and sixty-eight (62.45%), fifty-nine (21.93%) did not have dental fluorosis while one hundred and nine (40.52%) had dental fluorosis. An independent t-test was then carried out to determine whether there was a significant difference in working memory between those with dental fluorosis and without dental fluorosis. The mean working memory for the population without dental fluorosis, 128.01, is higher than that of the community with dental fluorosis, 123.52, figure 3.32.

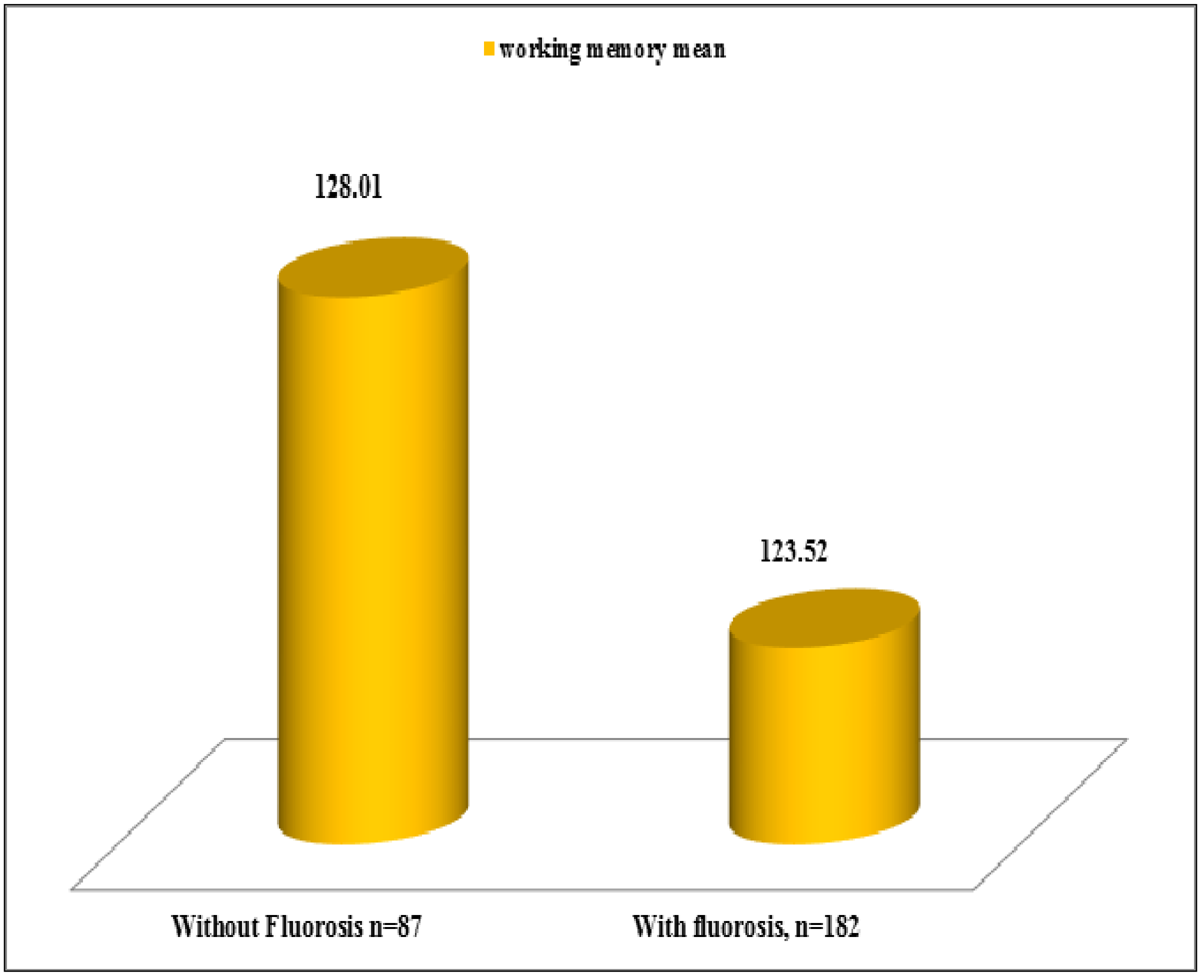

Figure 3.32: Mean working memory in the participants with normal teeth and those with fluorosed teeth

Levene's test, p>0.05, suggests that we reject the null hypothesis and conclude that the populations have equal variances in working memory. The independent t-test, t (267) = 1.475, p = 0.141, suggests that there was no statistically significant difference in working memory between populations with dental fluorosis and those without dental fluorosis.

3.6.5.2 Working memory individuals aged 13-15 years: Association between working memory and severity of dental fluorosis

The working memory was correlated of 269 individuals aged 13-15 years had their working memory associated with the severity of dental fluorosis TF scores. The normal teeth TF score zero had a nonsignificant, negative and weak association with a Spearman’s, correlation R_S=-0.053, p=0.385 while TF score 1-3 had a weak positive association which was insignificant, with R_S=0.095, P=0.119; TF score 4 had a fragile positive and nonsignificant association, with R_S =0.002, p=0.978 and TF score 5-9 was also insignificant with a weak and negative association where coefficient R_S= 0.003, p=0.964.

There were no associations between the mean TF scores zero R_S=0.053, TF scores 1-3 R_S=0.095, TF scores 4 R_S =0.002, and TF F scores 5-9, with R_S= 0. 003. Therefore, the null hypothesis that there was an association between the working memory for children affected by varying severities of dental fluorosis is rejected, and the alternative that there were no differences in the working memory of children with for adolescents with varying severities of dental fluorosis is accepted.

CHAPTER 4

DISCUSSION

4.1 Socio-demographics

4.1.1 Parental level of education

The study found that only 2.5% of the respondents' parents did not have formal schooling. The Kenya 2014 Demographic and Health survey Atlas for County level health indicators showed that literacy levels were 91-96% for the County(62).

4.1.2 Social demographics for the adolescents

4.1.2.1 Gender and age

Out of the 269 who took part in the study, most of them 66.2% were females while 33.8% were males. This significant difference between the genders may be explained by the willingness of the girl's girls to participate in research than the male boys. The girls have received support externally through the sanitary towel initiatives from both the Ministry of Education and also organisations like "Inua Dada" foundation(63). In a report on the status of the boy child in Kenya by the National Gender and Equality Commission 2015, there was a perception by 92% of the respondents that the boy child was losing out on gender equality agenda(64). The report also shows higher dropout rates for the boys than the girls at class four and five while at enrolment, the boys are equal to or even more than the girls. The report concludes that also though there is a high premium placed on the boy child due to the patriarchal society, there is more focus on the girl child through selective interventions and programmes that push the boy child to develop low self-esteem and also lose confidence.

Majority of the participants, i.e. 66.7% were age 13 because this is the age at which most of the Kenyan children are either completing or about to end their primary education, and they have six permanent teeth fully erupted in each quadrant.

4.2 Water and minerals

4.2.1 Heavy metals and fluoride

The fluoride concentration in the water sources ranged from 0.8mg/l to 15.0mg/l while the heavy metals were not detected. Majority of the water sources 81.81% had a level above 2mg/l. The current study finding is in comparison to Nair. K.R et al. 1984 which showed that majority of the boreholes 61.45% had fluoride ion concentration above 1 mg/l while 19.5% had above 5.0gm/l while in the current study it was 27.7% that had water with fluoride above 5.0 mg/l(13). Nair et al. found that most boreholes in Kajiado, 65.15% had water above 1.1 mg/l. Most of the children took water from the surrounding borehole, and the tap water came from these sources because the county government water supply is not reliable.

The household water fluoride 39% had water with fluoride level 1mg/litre, and below, while the rest took water above 1mg/l.

4.2.2 Schools in low, medium, and high fluoride areas: The lowest level of fluoride according to the water source was 0.8mg/l while the highest was 15.0 mg/l. The low fluoride compares with what Malago et. Al., have reported that Kenya was one of the countries in Africa with the highest level of water fluoride(65).

4.2.3 Drinking household water with a low, medium, and high fluoride:

There 45.72% had high household water fluoride, 15.24% had medium household water fluoride, while 39.03% had low household water fluoride. Therefore the majority of the residents either took high or medium water fluoride in their households. Nair et al. in 1984 showed that 67.7% of the water in the former Kajiado district current Kajiado County had more than 1mg/l of fluoride which is in agreement with the present study in which 60.96% of the studied households took water with fluoride above 1mg/l(13).

4.3 Prevalence and severity of dental fluorosis

The study found an overall prevalence of dental fluorosis was 67.7% in comparison to that of the Kenya National Oral Health Survey that found a prevalence of 41.4%(29). The difference might be due to the study being done in an endemic fluoride area with pockets of low fluoride water while that of the national health survey was distributed throughout the country. The prevalence of dental fluorosis was in agreement with the studies by Makhanu and Ng'ang'a which showed a prevalence of 68.1% and 76% respectively(30,31). However, it is lower than what was reported by Mutave who documented a prevalence of 93.4% (14). Dental fluorosis prevalence was higher in the high fluoride areas than in the low fluoride areas. However, 41.18% of those in the low fluoride areas had dental fluorosis, 63.63% of the medium fluoride had dental fluorosis while 79.17% from the high fluoride areas had dental fluorosis. This study records a lower fluorosis prevalence than the study by Sudhir in 2009 in which there was 100% dental fluorosis in all areas with different levels in drinking water fluoride(66). The levels considered by Sudhir were level 1 less than 0.7ppm, level 2 0.7-1.2ppm, level 3 1.3-4.0 ppm and level 4 more than 4.0 ppm. Just like in this study, there was dental fluorosis present even in low fluoride areas.

Manji also found that even in low fluoride areas with less 1 ppm of water fluoride, dental fluorosis was still very prevalent(67). Akpata also found a prevalence of 90% for children taking water between 0.5-2.8 ppm(68) an indication that even in common fluoride areas, dental fluorosis was still present and therefore other sources of systemic fluoride to the body are still possible.

In this study, the medium fluoride water area 1.1-2.0 mg/l fluoride had a prevalence of dental fluorosis of 63.63%, Manji in a study in Kenya area with 2 ppm fluoride found 100% prevalence of dental fluorosis(67).

The possible explanation of this is that in endemic fluoride areas there is the incorporation of fluoride in food materials that are ingested into the body becoming available systematically(69). Also, the temperature of Kajiado is quite high, necessitating a higher intake of water, and Nanda et al. suggested a positive correlation between mean annual temperature and total intake of fluoride(70).

4.3.1 Dental fluorosis prevalence by gender and age

There was no age or gender preference which is in agreement with the study by Nganga that showed no gender bias for dental fluorosis(30).

Insignificant differences in the severity and prevalence of dental fluorosis were observed with gender. A study by Opinya et al. did not find any gender preferences, and similar findings were reported by Nganga et.el., and Hamdan where there were no gender differences in the prevalence and severity of dental fluorosis(21,30,71). Also, the severity of dental fluorosis did not change with age; this finding is unlike the study by Sudhir in which the severity of fluorosis showed a weak negative correlation with age(66).

4.3.2. Fluoride concentration in water and prevalence and severity of dental fluorosis

The predictive factors for dental fluorosis were high household water fluoride and dam/well as water source. Significant differences were also noted between the prevalence of dental fluorosis and its severity and the area water fluoride content $p \leq 0.0001$ at 95% CL.

The fluoride concentrations in the drinking household water varied from the low, medium, high fluoride. A dental fluorosis prevalence of 46.67% was observed for children whose household water had low fluoride concentration. Those adolescents whose water had a medium fluoride concentration the prevalence of dental fluorosis of 66.67%; while 95.18% from high household water fluoride had dental fluorosis. Heller found that children who consumed water of fluoride 0.3 ppm and below had a prevalence of 13.5% of dental fluorosis, those who drank water between 0.3-0.7 ppm had a prevalence of 21.7% of dental fluorosis while for water fluoride between 0.7-1.2 ppm a fluorosis prevalence of 29.9% was found and a prevalence of 41.4% for water fluoride of 1.2ppm and above(26). The finding agrees with the study by Opinya, which showed that high water fluoride led to the high prevalence of dental fluorosis(21). Heller also revealed that an increase in water fluoride led to the rise in the prevalence of dental fluorosis(26). Also, a significant association between household water fluoride content and presence and severity of dental fluorosis $p=0.0001$ at 95% CL. These findings are similar to those of Heller et al. and are also in agreement with a study in Guadiana Valley North-Western Mexico(26,27). Shekin C also found that the prevalence and severity of dental fluorosis increased with increase in the concentration of fluoride in water(28). The prevalence and severity of dental fluorosis were noted to be higher among the individual whose household had high fluoride concentrations. At the WHO recommended an optimal fluoride (1 ppm) level of about fifty-four (20%) of the participants demonstrate fluorosis(69,1).

The children with high household water fluoride are twice more likely to have dental fluorosis than those with low household water fluoride. The household water fluoride is a stronger and better indicator of water fluoride intake in comparison to the area and school water fluoride content.

4.4 Intellectual efficiency

Intellectual efficiency is the measure of the ability of an individual to learn verbal materials and logical reasoning, abstract thinking, and classifying things(73). Therefore it measures the ability of an individual to analyse, synthesise, have a visual memory, and have spatial imagination and visual coordination.

Wide Range Achievement Test (WRAT) scores are correlated with cognitive ability in healthy subjects and usually have high stability over time(61). WRAT can be used to assess Intelligence Quotient (IQ) and Intellectual Efficiency (IE). The WRAT does not do a full assessment of academic abilities, but it is a domain-specific in identifying those who may have disorders of learning. The WRAT was chosen as the tool because of the ease with which the test could be administered. Hence, it is efficient regarding time, and it has generally accepted in the field. It is also flexible accordingly can be used with small groups and even individuals. Hence, it is suitable for screening those with learning disabilities. The distribution of IE among the students was normal, with the highest percentage having an average score.

4.4.1 Intellectual efficiency and Parental education

A Tukey for multiple comparisons shows the significant differences in the IE was between children whose parents had primary education (IE 97.4±12.2) and those whose parents had a high school education with an IE 104.6±13.3 with mean difference= -7.19495, se=2.018, p=0.006. However, the differences between the primary, college, and university levels of education were not significant. Sudhir et al., found no association significant between IQ and parental education, thus partly agreeing with this study(74). Xiang also found no significant relationship between parents level of education and children's IQ(75).

The other demographic factors, i.e. whom the children lived with, whether it is both parents or none, number of siblings, the source of drinking water, if they had suffered from any disease, time of migration into the sub-county, a parent level of education. Alternatively, whether the child carries water to school did not significantly affect IE when subjected to multiple linear regression. Sudhir found that the socio-economic factors like family income and parental level of education did not affect IQ substantially and this is in agreement with Xiang et al. (74,75)

12Also, there were no significant differences in IE according to age. Suleman Abbas Khan et al. did not find any statistical difference in IQ of children from different age groups Who Were 6-11-year-olds (76). Sudhir et al. in their study among 13-15-year-olds did not find any correlation between age and IQ(74). Suleman Abbas et al. has confirmed gender, Sudhir et al., Zhao et al. whom all did not find any significant correlation between gender and IQ(74,76,77).

4.5 Intellectual efficiency for the adolescent in school areas with varying fluoride concentrations in water: The varying levels in the school water categorised as low, medium, and high fluoride areas had the distribution of the children with their mean IE according to fluoride areas was 104.9+/- 1.46 for low fluoride areas. The children attending schools in the medium fluoride area had a mean IE of 106.3+/-13.6, and those in the high fluoride areas they had a mean IE of 97.8+/-12.6. There were no differences in the mean IE for the children living in the low fluoride area and those living in the medium fluoride area with a Post Hoc test Tukey, mean difference in intelligence -1.45098, p=0.862 at 95% CL. The IE of the children from the low and the high fluoride area indicated significant differences in the mean for IE with a Tukey Post Hoc test with a mean difference of 7.13235, with a standard error 1.89666, p≤0.001 at 95% CL. The IE of adolescents in the medium was compared with that of individuals living in a high fluoride area, and there was a mean significant difference with a Post Hoc test Tukey, where the mean difference was 8.58333, standard error =2.51263, p≤0.002 at 95% CL. These findings are similar to what Sebastian et al. found in Mysore(43). They found that the mean IQ in the medium area Belavadi (fluoride 1.2 ppm) was higher than the low fluoride area Naganahally (fluoride 0.4 ppm) and the high fluoride area Nevale (fluoride 2.0ppm). In both this study and Sebastian's study, it was found that even though there was a difference in mean IQ in low and medium areas, the differences were not significant but the difference between high and low fluoride areas and high and medium fluoride areas was significant. Aravind et al. found a mean IQ of 41.03 for low fluoride (less than 1.2ppm), 56.68 for medium fluoride area (1.2-2.0) and 31.59 for high fluoride area (above 2ppm)(78). Similarly, Eswar et al. found a higher mean IQ in low fluoride areas of 88.8 than that in high fluoride areas of 86.3(79).

The findings show that the adolescents who lived in high fluoride areas had a lower mean IE according to the WRAT test. Majority of those below average 9.7% were from high fluoride areas. Also, those adolescents with average IE 40% were from the high fluoride areas. The present study 67% of those gifted was from low fluoride while 33% were from medium fluoride. The current study also found that from the high fluoride areas none was gifted, and only 31.1% had an above average IE in comparison to 42.2% from the low fluoride area. In this study, all, i.e. 100% who were intellectually challenged and 76.47% who had below average intellect were from high fluoride areas (≥2.1mg/l). The findings in this study are comparable to a survey by Sudhir K.M in 2009 in which they found that about 70.8% of grade 5 (intellectually impaired) were from high fluoride, i.e. level 4 (≥4.5mg/l concentration of fluoride) and no child from this high fluoride had Grade 2 (definitely above average) intellectual capacity and grade 1 (intellectually superior) intellectual capacity(74). In a similar study by Sebastian ST, they found that the worst intelligence grades were observed with water fluoride of ≥4.5mg/l(43).

Sebastian ST in Mysore found that high fluoride area 2.0mgF/l had more participants' 63.7% with marginal IQ compared to medium fluoride area 1.2mgF/l with 42.2% and low fluoride area 0.4mgF/l with 46.7%. In the above and high average only 4.4% of those who lived in high fluoride area while 7.4% of those who lived in medium fluoride area and 6% of those who lived in low fluoride area(43). Therefore as the water fluoride increases, there is a decrease in intellect.

The IE for the individuals was similar to a study by Sebastian ST in which he found that school children who were residents in higher than normal water fluoride areas demonstrated the more impaired development of intelligence in comparison to those in normal and low water fluoride areas(43). Zhao et al. in 1996 found the average IQ of low fluoride area to be 105.21 while the high fluoride area had an average IQ of 97.69(77). Saxena in 2012 found that areas with low water fluoride ≤1.5 ppm had the lowest IQ mean grade (best intelligence) while high water fluoride areas ≥4.5 ppm had the highest mean grade of IQ (worst intelligence)(46).

4.5.2 Intellectual efficiency for the adolescent using household water with varying fluoride concentrations in water: The fluoride concentration in the household drinking water was grouped as low, medium, and high fluoride in household water and the mean IE of the children using water with a low fluoride concentration was 107.48. However, the children whose household water had a medium fluoride concentration their mean IE was low, and it was 96.21, and it was close to the mean IE of 96.20 for the adolescents whose drinking water had high fluoride concentration. The difference in IE between low and medium and low and high household water fluoride was significant with Tukey post hoc p=0.000. However, an insignificant difference between medium and fluoride content in high household water was noted with Tukey post hoc p=1 at 95% CL. Similar to the findings of Seraj B in Makoo, Iran. They demonstrated that the average IQ of children living in standard water fluoride (0.8+/-0.3 ppm) was higher than those living in high water fluoride (5.2+/-1.1 ppm). They also found that even though the IQ of normal fluoride water residents was higher than those who resided in high and medium water fluoride (3.1+/-0.9) areas the difference in IQ of children living in high and medium water fluoride areas was not statistically significant(45).

When the household water fluoride was considered, it showed that 100% of the intellectually challenged were from medium fluoride household water. Those who scored below average and average 35.91% were from high household water fluoride, 33.18% from medium household water fluoride while 30.91% were from low household water fluoride. However, this near equal distribution changes in the above average and gifted. Majority of those with high IE categories 77.08% were those with low household water fluoride, while only 14.58% were from medium household water fluoride and only 8.33% were from high household water fluoride. This result is similar to a study by Li et al. in 2000 in which 49.1% in medium and 47.5% in severe fluorosis areas had a low or borderline IQ≤79, and none in both areas had IQ≥120(80).

4.5.2 IE with prevalence and severity of dental fluorosis

Most of those with dental fluorosis 88.46% had an IE of average and below-average while 85.06% of those without dental fluorosis had an IE of average and above average. Only 11.54% of those with dental fluorosis had an IE score of above average and gifted while 31.03% of those without dental fluorosis had a score of above-average and gifted. The differences in the IE was comparable to a study by Suleiman Abbas in 2015, in which they found that majority, 76.3% of the children free of dental fluorosis had Grade 2 IQ (definitely above average intellectual capacity), and all those with Grade 1 (intellectually superior) were free of dental fluorosis(76). The study findings showed that the individuals with the presence of dental fluorosis were 13.19%, and they had a below-average IE while those without dental fluorosis were 12.64% were below average and mentally challenged. The current study finding contradicts the observation by Khan 2015, where all children with Grade 5 IQ (intellectually impaired) had severe dental fluorosis(76).

The adolescents with normal teeth had a higher mean IE 103.87 in comparison to those with dental fluorosis who had a mean IE of 99.044. Thus there was a significantly lower IE among those with dental fluorosis. Khan also found mean IE of those without dental fluorosis to be higher 110.1+/-9.0 while those with dental fluorosis had a lower IE of 87.12 ±7.5(76). The relationship of IE to the severity of dental fluorosis in this study only significantly decreased in TF 1-3, and although it decreased in TF 4 and TF 5-9, this was not statistically significant. Ding in 2011 found that the mean IQ in the group with moderate dental fluorosis was not significantly different from those with normal, very mild and mild dental fluorosis(81). However, Sudhir in 2009 found that there was a significant association between the increase in the severity of dental fluorosis and IQ(74).

4.6 Working memory scores and levels of working memory

The individual's ability to retain information in a readily accessible form is referred to as working memory(82). It is the little bits of information which the mind can hold and use to execute cognitive tasks. It frequently is related to learning ability, problem-solving ability, comprehension, intelligence, executive function and information processing in all sorts of animals and people of all ages.

Reaction time is a relatively sensitive indicator of toxicant and medication indicator(82). The WISC-V digit span forward is used to assess attention and concentration(41). The executive function is an assessment of abstract reasoning and the performance in this test is related to aspects of both abnormal and normal development of the child.

It is essential to have sufficient working memory so that concepts can be formed, which in learning is critical. Thus insufficiency in working memory may make learning difficult because knowledge is built on concepts. For example, if a pupil knows that Kenya got independence in 1963, they can construct an idea on this that it is the year Jomo Kenyatta became President of the republic.

Therefore in learning a good working memory is essential(83). Kane et al. showed that individuals with a low span working memory had more problems attending daily life chores(83).

It has been suggested that children working memory failures are a significant part of learning disabilities(84). That those children frequently accused of making no effort to follow directions tested to have low working memory ability. For the needed duration, the children were either not able to pay attention continually, could not stick to the task goal or are unable to remember the instructions. Therefore children with low working memory perform poorly in school (84).

Animal studies had shown that rats exhibited memory and learning deficits when they were given water with fluoride while those that were not had any gaps in behaviour (28, 29, 30).

4.6 WORKING MEMORY

4.6.1 Parental education

There was no association between parental level of education and working memory ANOVA p=0.688. Sebastian et al. in 2015 found no significant association between parental education level and family income with IQ(43). However, Zhao et al. found a correlation between the educational level of the parents and the IQ of the children(77). Zhao found that children of parents who had higher education had statistically significant higher IQ in comparison to the other children.

4.6.1.1 The children's social demographics and working memory:

Gender and age: The difference in WM scores between the male, and the females was significant with an independent samples test and a Levene's test for equality of variances with equal variance not assumed p=0.011. There was no significant difference according to age. Sebastian found no significant association between age gender and IQ(43). Zhao et al. found no association between IQ and gender(77).

4.6.2 Working memory scores and levels of WM with fluoride concentrations in water:

The working memory of the children attending schools in the schools grouped as low, medium, and high fluoride areas. When those with average, low average, very low and extremely low working memory were considered, only 9.1% of those from medium fluoride areas were in this spectrum, 13.2% of those from low fluoride areas were in this category while 27.5% of those from high fluoride areas were in this low spectrum of working memory. The low range of working memory in this study is similar to Aravind in 2016 who found that among children in high fluoride areas the percentage with below-average IQ was more significant (59.37%) when compared to low fluoride areas (15.6%) and medium fluoride areas with none(78). Liu et al. also found low and borderline IQ that was significantly more in high fluoride areas than in low fluoride areas(80). For the extremely high and very high working memory, 66.2% of those in low fluoride areas fell in this category while 81.1% of those in medium fluoride areas were in this category and only 57.2% of those from high fluoride areas were in this category. Aravind found a similar proportion of children with IQ grades II and III was more significant in the low water fluoride region, thus, 84.37% and medium water fluoride areas, i.e. 89.55% than in high fluoride areas thus, 40.62% and this differences were statistically significant(78). Poureslami found a higher percentage of students ranked excellent, above average and average in low fluoride areas than in high fluoride areas(88).

4.6.2.1. Mean working memory with water fluoride areas

When mean working memory according to water fluoride areas was considered, the medium fluoride areas had a mean of 133.06+/-17.3 while the low water fluoride areas had a mean of 125.60+/-21.5 and high water fluoride areas had a mean of 123.13+/-24.9. There were significant differences in working memory means of the different fluoride areas and post hoc test showed differences between low and medium p=0.033, medium and high p=0.001 but non-significant difference between high and low p=0.593. Choi et al. found that although there was no significant difference between working memory and water and urinary fluoride, they were in the anticipated direction(89). Ding Yunpeng et al. in 2010 found that low fluoride concentrations in drinking water had adverse effects on the children's intelligence and dental health and when they considered urinary fluoride they found there was a decline in the mean IQ as the urine fluoride increased(81). Eswar also had similar findings to this study where he found no statistically significant difference between the mean IQ in low and high water fluoride areas even though the low fluoride mean IQ was higher than the low fluoride area(79).

4.6.2.2. Low, medium and high fluoride concentration in drinking water and working memory

The categorisation of working memory according to household fluoride majority of the mentally challenged came from medium and high household water fluoride with 57.14% from medium and 42.86% from high household water fluoride. The finding that mentally challenged adolescents were the ones who used water with medium and high fluoride concentrations was in agreement with the study by Khan which found that majority of the children (74.8%) living in low fluoride areas had definitely above average intellectual capacity. None was intellectually impaired and definitely below average(76). From the high fluoride area, Khan found that most of the children (58.1%) were intellectually average, and none from the high fluoride area was intellectually superior. Karimzade in 2014 found that 57.8% of those from high fluoride region had mental retardation or borderline intelligence and it was only 10% in the low fluoride region(90).

There is an association between household water fluoride and working memory Chi-square =25.84, p=0.001. ANOVAs showed a difference between groups of adolescents with low household water fluoride ≤1.0mg/l, medium 1.1-2.0mg/l and high household water fluoride ≥2.1mg/l. Tukey post hoc test showed the difference in working memory between low and medium, low and high but not between medium and high. The differences in working memory between low and medium, low and high in agreement with what Kundu found in Delhi that there were significant differences in the IQ for children in high and low fluoride areas with low fluoride areas having a higher IQ(91). There was an association between working memory of adolescents with normal teeth in low household water fluoride, when compared with medium and high, ANOVAs F=9.473, p=0.000.

4.6.3.3 Working memory scores and levels of working memory with prevalence and severity of dental fluorosis

The mean WM for those without dental fluorosis was (128.01+/-22.39) higher than for those with dental fluorosis (123.52+/-23.79). However, there was none significant difference in those with and those without dental fluorosis. There was also no change in working memory when the severity of dental fluorosis was considered. Li F et al. in 2009 found IQ as significantly reduced among children with severe fluorosis in comparison to those without dental fluorosis(92). Although not statistically significant IQ was noted to decrease with an increase in the severity of dental fluorosis, an increase in the severity of dental fluorosis indicates that high doses of fluoride are poisoning. The finding in the current study is unlike several studies that have there to be a difference in intellect between those with and those without dental fluorosis. Shivaprakash found that children without dental fluorosis had a higher IQ than those with dental fluorosis(48). Khan in 2015 found that with a rise in the dental fluorosis severity, there was a decrease in intellectual capacity(76).

4.7 Conclusion

Water fluoride significantly affects the degree and severity of dental fluorosis, and that there is a negative association between household water fluoride and WM and IE. Although those with dental fluorosis have a lower IE and WM, the degree of dental fluorosis does not affect the IE and WM

4.8 Recommendations

1. Further studies in this area are required with other factors controlled, e.g. maternal IQ and nutrition and incorporation of urine analysis
2. Both levels of government should prioritise clean and safe water supply to all the citizens through defluoridation and borehole water control.

4.9 Limitations

Inheritance influences intellect. Parental IQ is often the single most significant determinant of a child's IQ. When it is controlled for, any remaining effect of F on IQ is much easier to detect. It is best to measure parental IQ directly rather than relying on surrogate indirect measures such as income or years of education; while measuring one or both parent's IQ will require more significant effort and expense. No studies have obtained IQ test results for both parents, but if that is possible, that may be worth doing. Practical and cultural considerations will likely determine whether this is feasible. Most studies that have obtained parent IQ have obtained it from the mother.

Only the fluoride content in water was analysed as the marker for exposure to fluoride, and therefore this does not account for other sources of fluoride to the body. Urine would have been a better measure of all sources of fluoride to the body[43]. Measured fluoride urine concentration of mothers during pregnancy and the IQ of their children later is a stronger evaluation than dental fluorosis. Kenya seems like an ideal location to replicate and perhaps improve on that study.

Dental fluorosis is not a useful biomarker of prenatal exposure since exposures from birth almost entirely determine it to about age eight. If the child had different fluoride exposures than the mother (foetal exposures), then fluorosis will not be ideal; therefore it is essential to find participants who had mainly exposure from drinking water and whose mother also had the same primary fluoride exposure from the same drinking water.

In order to evaluate the effects of fluoride on the fetus and children, a long term study would give a more in-depth analysis.

Nutritional status was also not considered, and this has been shown to affect intelligence[44, 45].

Although children who had changed their water source since birth were excluded, recall bias is still possible and fluoride in water changes according to seasons.

The difference in household water fluoride may be an indicator of parental and social knowledge on the effects of fluoride, and therefore an attempt is made to get fluoride free Water source for domestic use.

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APPENDICES

APPENDIX 1: TIME SCHEDULE

ACTIVITY	2015/2016	2016/2017	2017/2018
Proposal writing	Dec-Feb		
Submission to the ethical committee and BPS UON and Approval	March		
Pretesting data collection tools		September	
Data collection		October-November	
Data entry		December	
Data analysis			January
Thesis writing			February to march
Thesis submission			April
Thesis defence			August

APPENDIX 2: BUDGET

Item	Unit	Unit Cost (Kshs)	Total cost (Kshs)	Justification
STATIONERY				
Files	300	30	9000	For storing questionnaires and consent forms.
Printing paper	10	1000	10000	For printing of documents
Pens	50	30	1500	
Pencils	50	20	1000	
Rubbers	50	10	500	
Sharpeners	20	15	300	
flash disk	2	2000	4000	
Internet access	7500/month	10	75000	
Printing	10/page	2000	20000	

Binding	150	30	4500	
CLINICAL EXAMINATION MATERIALS				
Latex gloves (pkts)	15	400	6000	
Masks	4	600	2400	
Wooden spatulas(pkts)	5	400	2000	
Manual for tests	1	200000	200000	
PERSONNEL				
Principal investigator	30 days	1000	30000	
Supervisors	3	5000*6days	30000	
Statistician	1	20000	20000	
Secretarial services and assistants	30 days	2000	60000	
SUBTOTAL			476,200	
10% contingency			47620	
total			523820	

APPENDIX 3: CONSENT FORM

Project Title: THE RELATION OF DENTAL FLUOROSIS TO INTELLECTUAL EFFICIENCY AND WORKING MEMORY IN 13-15-YEAR-OLDS LIVING IN LOW AND HIGH-WATER FLUORIDE AREAS IN KAJIADO COUNTY.

Purpose of the study

Dental fluorosis affects so many households in the country and the primary source of fluoride that causes the fluorosis is drinking water. A comparative study on the intellectual efficiency and working memory in children living in low and high fluoride areas will help to the governments to be keen on defluoridation and sensitise the society on the impact of fluorosis on the central nervous system.

Procedure to be followed

Your child shall be interviewed; then they shall be examined by trained and qualified health professionals and later on do a test. I wish to request for your permission for your child to participate in the study that shall form part of my degree work.

At the end of the study, you shall be informed of the results. The results shall also be communicated to the community and sponsors, and both in the local and international scientific conferences.

Risks

There are no risks in this study since no invasive procedures shall be performed on your child.

Benefits

The results of this study shall assist in sensitising you and other Kenyans on the effects of excess fluoride on the intellectual efficiency and working memory of the children if it's there. The results shall also be used to advise policymakers and healthcare professionals on the effect of excess fluoride on intellectual efficiency and working memory of the children.

Confidentiality

All the information that shall be obtained from your child shall be confidential to protect their privacy. Confidentiality shall be achieved by giving codes to their medical records and questionnaires thereby avoiding using their name when gathering information from them. The report shall be accessed by professionals involved in the study and who are authorised to do so but cannot recognise your child's identity. There is no identity of any participant that shall be disclosed in any public conferences, reports or publications.

Participation

I……………………………………. parent/guardian of …………………………………… school do now freely consent/do not consent to my child participation in the said study.

Dr……………………………………… has explained what is required of my child. I do understand that no harm will be caused and my child can withdraw at any time without any adverse consequences to him/her. I am also informed and understand that all the information about my child shall be treated in confidence.

Parent/Guardian Signature…………………………. Date……………………

I, the undersigned, have fully explained the relevant details of this study to the parent/guardian of………………………………………. of………………………school. By my training and research experience in this field, I am qualified to perform this role.

Signature…………………Name of PI…………………………. Date…………………….

Signature……………......Name of witness……………………Date……………………...

MAELEZO YA KUTAFUTA IDHINI KUTOKA KWA WATOTO WATAKAOSHIRIKI KATIKA UTAFITI.

Kiini cha utafiti

UTAFITI WA KULINGANISHA KIWANGO CHA UEREVU NA KUKUMBUKA KATIKA WATOTO WA MIAKA KUMI HADI KUMI NA MITATU WANAOISHI KATIKA SEHEMU ZA KIWANGO CHA FLOROSI CHA CHINI NA CHA JUU.

Lengo la utafiti

Flurosi ya meno huadhiri watu wengi katika nchi ya Kenya. Kiiini kikuu cha florosi hii ni maji yanayo tumika kupika na kukunywa. Utafiti kuhusu jinsi florosi inavyoathiri uerevu na ukumbuko utasaidia washika dau ikiwemo serikali kuweka miundo msingi ili kukumbana na tatizo hili.

Kanuni za utafiti

Mtoto wako atahojiwa na kisha afanye mtihani wa kupima uerevu wake. Baadaye atapimwa shuleni na daktari wa meno aliyehitimu kwa kazi hiyo. Utafiti utakapokamilika utajulishwa matokeo yake pamoja kuyawasilisha kwa jamii zenu, wadhamini wautafiti huu, wanasayansi wa hapa nchini na wakimataifa.

Madhara na manufaa ya utafiti

Hakuna madhara yoyote yanayotarajiwa katika utafiti huu kwa mtoto wako. Matokeo ya utafiti huu yatatumika katika kuboresha kiwango cha maji yanayotumika katika jamii. Ningependa pia kukueleza kuwa hakuna gharama yeyote kwako kushiriki katika utafiti huu na unaweza jiondoa wakati wowote bila kuhitaji kuomba ruhusa.

Hifadhi ya nakala ya habari utakayotoa

Habari yote nitakayokusanya kutoka kwa mtoto wako zitahifadhiwa kwa siri na kutumiwa katika utafiti huu. Majina ya watoto binafsi watakaoshiriki hayataandikwa mahali popote wakati wowote. Nakala zote za habari kuhusu mtoto wako zitafungiwa katika makabati maalum wakati wote wa utafiti huu.

Tutasistiza usiri huu katika kusimamia habari tutakazopewa ili kuzuia kujulikana kwa watakaoshiriki katika utafiti huu. Hakuna majina yatakayotumika katika vikao vya sayansi kwa umma na ripoti zitakazochapishwa katika majarida haya.

Idhini yako na sahihi

Nimesoma maelezo yaliyoko hapa juu na nimekubali kwa hiari yangu kuwa mtoto wangu ashiriki katika utafiti huu;

………………………………………. ………………………………………..

Jina la Mshiriki Sahihi ya Mshiriki na Tarehe

Mimi niliyepewa jukumu la kupeana maelezo kuhusu utafiti huu kwa mshiriki aliyetajwa hapa juu, nimepeana maelezo kamili kulingana na masomo na ujuzi wangu katika kazi hii. Kwa hivyo ninahitimu kufanya jukumu hili

…………………………………… ……………………………………………

Jina la mtafiti aliyetoa maelezo sahihi ya mtafiti na tarehe

………………………………………. Jina la shashidi sahihi ya shahidi na tarehe

APPENDIX 4: STUDY QUESTIONNAIRE

Project ID No. (Code);………………..

Section A; Social-Demographic Data (child)

1. Place of birth………………………………………
2. Date of birth……………………………………….
3. Age in years……………………………………....
4. Gender a) Male b) Female
5. Residence…………………………………………..
6. Schools name………………………………………
7. Whom are you living with?

   A) Parent B) Guardian
8. If parents state whether both or one
9. How many siblings do you have in your family?
10. What is the source of your drinking water?
    a) Tap water
    b) Borehole water
    c) Dam/well
    d) River
    e) Other
11. Were you born in Kajiado County Kajiado north subcounty?
12. Did you live in Kajiado North subcounty for the 1st seven years of your life?
13. If NO at what age did you move to Kajiado North subcounty?

14. Have you suffered from any other disease?

15. If yes to question 14, which one(s)

SECTION B (PARENT)

1. Do you stay in Kajiado County Kajiado North subcounty?
2. For how long have you stayed in Kajiado North subcounty?
3. Was your child (ren) born in Kajiado North subcounty?
4. If no when did they move to Kajiado North subcounty?
5. What is the source of your drinking water?
    a) Tap water
    b) Borehole water
    c) Dam/well
    d) River
    e) Other
6. Has this been your only source of water since the birth of your child?
7. If no what is the other source?
8. How long did you use the other source?
9. Does your child carry water to school?
10. If yes what is the source of this water?
11. What is your level of education?
    a) No formal schooling
    b) Primary school
    c) High school
    d) College

e) University

12. What is your main source of family income?

13. How much money approximately do you make per month?

14. Do you live in your own house or you pay rent?

SECTION C

Distribution of TFI Scores by tooth surface

16	15	14	13	12	11	21	22	23	24	25	26
46	45	44	43	42	41	31	32	33	34	35	36

APPENDIX 5: THYLSTRUP-FEJERSKOV INDEX

The Thylstrup-Fejerskov (TF) Index	
Score	Criteria
0	Normal translucency of enamel remains after prolonged air-drying.
1	Narrow white lines were corresponding to the perikymata. [Dean = Questionable/Very Mild]
2	*Smooth surfaces:* More pronounced lines of opacity that follow the perikymata. Occasionally confluence of adjacent lines. *Occlusal surfaces:* Scattered areas of opacity <2 mm in diameter and pronounced opacity of cuspal ridges. [Dean = Questionable/Very Mild]
3	*Smooth surfaces:* Merging and irregular cloudy areas of opacity. Accentuated drawing of perikymata often visible between opacities. *Occlusal surfaces:* Confluent areas of marked opacity. Worn areas appear almost normal but usually circumscribed by a rim of opaque enamel. [Dean = Very Mild/Mild]
4	*Smooth surfaces:* The entire surface exhibits marked opacity or appear chalky white. Parts of the surface exposed to attrition appear less affected. *Occlusal surfaces:* Entire surface exhibits marked opacity. Attrition is often pronounced shortly after eruption. [Dean = Mild/Moderate]
5	*Smooth surfaces and occlusal surfaces:* Entire surface displays marked opacity with

	focal loss of outermost enamel (pits) <2 mm in diameter. [Dean = Severe]
6	*Smooth surfaces:* Pits are regularly arranged in horizontal bands <2 mm in vertical extension. *Occlusal surfaces:* Confluent areas <3 mm in diameter exhibit loss of enamel. Marked attrition. [Dean = Severe]
7	*Smooth surfaces:* Loss of outermost enamel in irregular areas involving <1/2 of the entire surface. *Occlusal surfaces:* Changes in the morphology caused by merging pits and marked attrition. [Dean = Severe]
8	*Smooth and occlusal surfaces:* Loss of outermost enamel involving >1/2 of the surface. [Dean = Severe]
9	*Smooth and occlusal surfaces:* Loss of main part of enamel with a change in the anatomic appearance of the surface. The cervical rim of almost unaffected enamel is often noted. [Dean = Severe]
Source: Thylstrup and Fejerskov, 1978 as Reproduced in "Health Effects of Ingested Fluoride" National Academy of Sciences, 1993, pp. 171.	

APPENDIX 6: SAMPLE INTELLECTUAL EFFICIENCY INSTRUMENT

WIDE RANGE ACHIEVEMENT TEST

DIRECTIONS FOR LETTER READING

If the Letter reading section is to be administered, say the following:

I want you to look at the letters on this line (point). Read me the letters one by one across the line.

A B O S E R T H U P I V Z J Q

DIRECTIONS FOR WORD READING

Begin the reading list on either the BLUE or TAN form by saying the following:

Look at each of these words carefully (point). Read the words across the page so I can hear you. When you finish the first line, go to the next line and so on.

Discontinue after the individual has missed ten consecutive words.

Allow 10 seconds for the individual to respond. If the individual is in the middle of a response, allow him/her to continue. If there is no response after 10 seconds move on the next by simply saying:

Try the next one, please.

After the first error (on either form) the individual should be asked to repeat the word which was missed. If the other word is said correctly, score as correct. No additional help should be given. Other than the first error per list, the individual should not be asked to repeat the word unless the examiner is unable to hear the word. When this occurs, say:

I could not hear you. Please say the word again just as you did the first time.

Scoring should be strict, but also take into consideration any problems which could be attributed to dialect or articulation difficulties;

BLUE READING

In	cat	book	tree
How	animal	even	spell
Finger	size	felt	split
Lame	stretch	bulk	abuse
Contemporary	collapse	contagious	triumph
Alcove	bibliography	horizon	municipal
Unanimous	benign	discretionary	stratagem
Seismography	heresy	itinerary	usurp
Irascible	pseudonym	oligarchy	covetousness
Heinous	egregious	omniscient	
Assuage	disingenuous	terpsichorean	

DIRECTIONS FOR NAME/ LETTER WRITING

If the name/letter writing section is to be administered, say the following:

Please write your identification number on this line (point)

Now I would like you to write some letters for me. Listen carefully and put the 1st letter I say here. The rest of the letters go in the spaces across this line.

Allow 5 seconds for each letter; if the individual is in the process of writing the letter after the time has elapsed allow him/her to continue.

A C F O W N G L D I K Y X

DIRECTIONS FOR WORD SPELLING

Say the following for the administration of the spelling dictation list:

I am going to read some words to you, and I would like you to write them in the numbered spaces on the form in front of you. Try to spell them correctly. I will say the word, then read a sentence with the word in it, and then say the word again. Please write the first word here (pointing to line #1) and then go down this way as I say each word. Try your best. If you are not sure how to spell a word, it is ok to take a guess.

No	Word	Sentence	pronunciation
1	And	Bill and Bob play together	And
2	In	They are in the pool	In

3	**Him**	**They saw him in town**	**him**
4	**Make**	**She can make a dress**	**make**
5	**Cook**	**We cook our dinner**	**cook**
6	**Must**	**We must do our work**	**must**
7	**Enter**	**Enter this way**	**Enter**
8	**Light**	**The light is a bright**	**light**
9	**Reach**	**She couldn't reach the ball**	**reach**
10	**Circle**	**A circle is around drawing**	**circle**
11	**Explain**	**Explain how it happened**	**explain**
12	**Correct**	**Put down the correct answer**	
13	**Ruin**	**The house was in ruin after the fire**	
14	**Material**	**The material was expensive**	
15	**Advice**	**My advice was forgotten**	
16	**Surprise**	**She may surprise you**	
17	**Believe**	**I believe you are right**	
18	**Brief**	**I received a brief note**	
19	**reasonable**	**His request was reasonable and just**	

20	**Quantity**	**He ate a large quantity of food**	
21	**Character**	**Her fine character was praised**	
22	**Success**	**Success makes people happy**	
23	**Executive**	**The governor is a state executive**	
24	**Decision**	**Your decision was accepted by all**	
25	**Recognise**	**He did not recognise me**	
26	**Anxiety**	**Floods create anxiety among people**	
27	**Opportunity**	**He had no opportunity for success**	
28	**Lucidity**	**He thinks best in moments of lucidity**	
29	**enthusiasm**	**People showed enthusiasm for the hero**	
30	**Conscience**	**His conscience was clear**	
31	**Possession**	**They took possession of the house**	
32	**belligerent**	**The soldier was belligerent and brave**	
33	**medieval**	**Medieval times were long ago**	
34	**charlatan**	**A charlatan is a pretender**	
35	**cacophony**	**A cacophony is a mix of harsh words**	
36	**camouflage**	**Camouflage is a natural defence for many animals**	

37	**acquiesce**	**To acquiesce is to comply with a demand**		
38	**pusillanimous**	**A pusillanimous person is weak in spirit**		
39	**malfeasance**	**The governor was found guilty of malfeasance in office**		
40	**vicissitude**	**Unemployment is a vicissitude which can have devastating effects.**		

DIRECTIONS FOR ORAL ARITHMETIC

Individuals older than always begin with written arithmetic the oral is only administered if they score less than 5 points on the written. Those who score 5 points or more on the written section are given the 15 points for the oral section, even though it's not administered.

DIRECTIONS FOR WRITTEN ARITHMETIC: 15 MINUTES

The time for administration is 15 minutes however if an individual indicates that they have completed all that they are capable of performing, it is permissible for the examiner to allow to discontinue this subtest before the allotted 15 minutes time limit.

Say the following for the administration of the written arithmetic section:

This is math's test. Look at the problem printed on these two pages (point) I want to know how many of this problems you can figure out. Look at each problem carefully to see what you can solve. Look at each problem carefully to know what you are supposed to do- add, subtract, multiply or divide- then put down your answer in the space on or below the line.

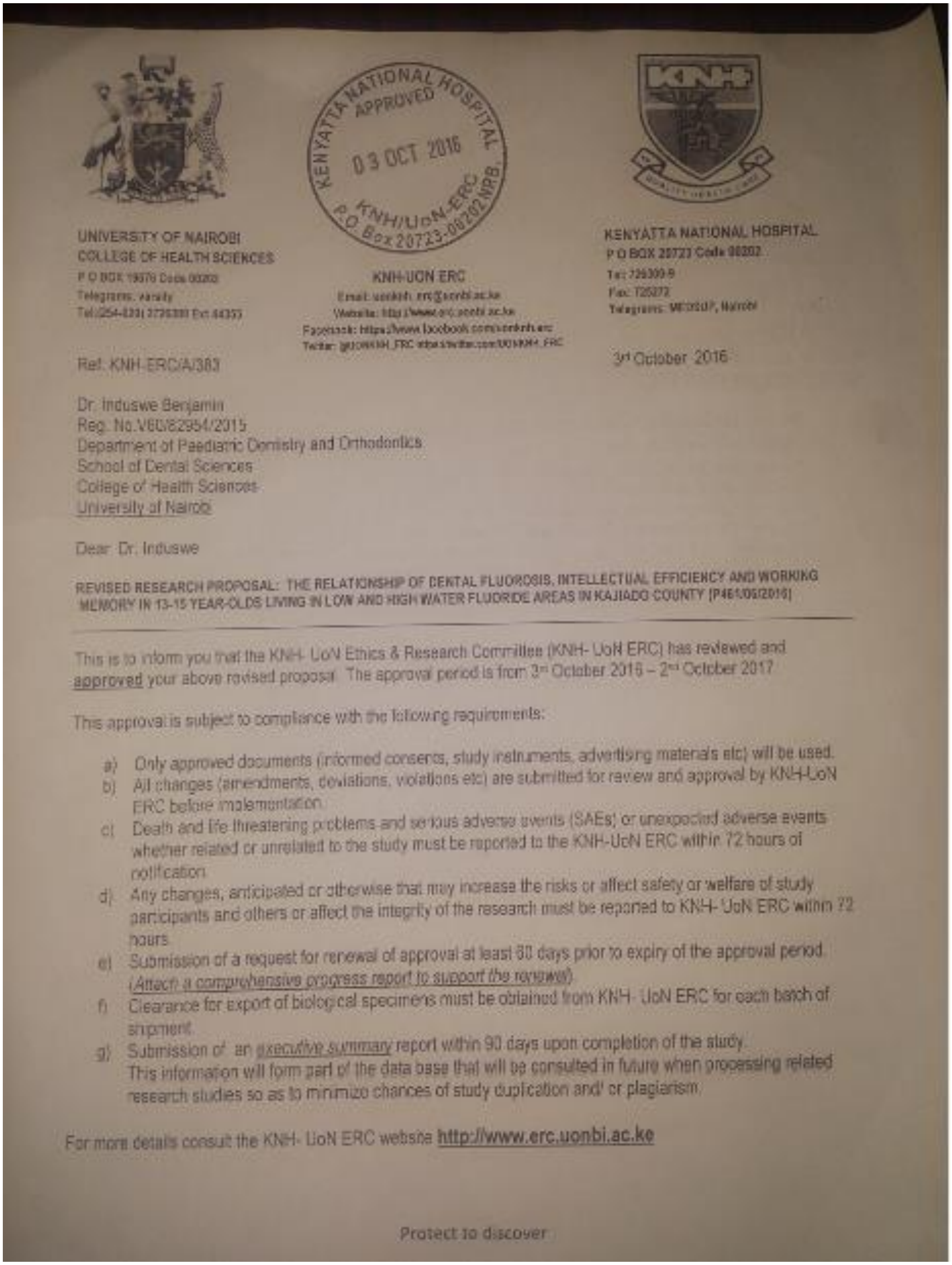
First, do the top row then the next. They are easier at the beginning then they get harder. I want you to try to finish as many as you can within 15 minutes. That's much time to work carefully, but don't spend too much time on any one problem. If you know you don't know how to do a problem, skip it and go on to the next.

Be sure to reduce all your answers to the lowest terms.

Check your work if you have finished all the problems you know how to do before the time is up. Raise your hand when you are done.

1+1	5-1	2+7	8-4	32+24+40
9+3	35-15	3*4	68+23	7*6
23*33	33-17	6/2	16/4	17*4
724-597	229+5048+63+1381	15/5	4527/9	1/3+1/3
2 ½+1 ½	823*96	.42=_%	¼*1/2	38*2.4
3/10÷3/46	6 ¼+1 5/8+4 ½	2/5 of 35	384÷27	6.23*12.7
2-_=1/4	10 ¼-7 2/3	Add -x-y-23 x-y+22	15% of 175	Write as a common fraction in the lowest terms: .075
$\frac{r^2-5r-6}{r+1}$	3p-q=10 2p-q=7		$F(x)=3x^2+x-7$	Reduce: $\frac{K^2+K}{K^2} * \frac{3K-3}{K^2-1}$

APPENDIX 7: THE LETTER FOR ETHICAL APPROVAL FROM KNH



KENYATTA NATIONAL HOSPITAL APPROVED
03 OCT 2016
KNH/UoN-ERC P.O Box 20723-00202 NRB.

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Twitter: @UONKNH_ERC https://twitter.com/UONKNH_ERC

KENYATTA NATIONAL HOSPITAL
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Telegrams: MEDSUP, Nairobi

Ref: KNH-ERC/A/383

3rd October 2016

Dr. Induswe Benjamin
Reg. No.V60/82954/2015
Department of Paediatric Dentistry and Orthodontics
School of Dental Sciences
College of Health Sciences
University of Nairobi

Dear Dr. Induswe

REVISED RESEARCH PROPOSAL: THE RELATIONSHIP OF DENTAL FLUOROSIS, INTELLECTUAL EFFICIENCY AND WORKING MEMORY IN 13-15 YEAR-OLDS LIVING IN LOW AND HIGH WATER FLUORIDE AREAS IN KAJIADO COUNTY (P461/06/2016)

This is to inform you that the KNH- UoN Ethics & Research Committee (KNH- UoN ERC) has reviewed and **approved** your above revised proposal. The approval period is from 3rd October 2016 – 2nd October 2017.

This approval is subject to compliance with the following requirements:

a) Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
b) All changes (amendments, deviations, violations etc) are submitted for review and approval by KNH-UoN ERC before implementation.
c) Death and life threatening problems and serious adverse events (SAEs) or unexpected adverse events whether related or unrelated to the study must be reported to the KNH-UoN ERC within 72 hours of notification.
d) Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH- UoN ERC within 72 hours.
e) Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. *(Attach a comprehensive progress report to support the renewal).*
f) Clearance for export of biological specimens must be obtained from KNH- UoN ERC for each batch of shipment.
g) Submission of an *executive summary* report within 90 days upon completion of the study.
This information will form part of the data base that will be consulted in future when processing related research studies so as to minimize chances of study duplication and/ or plagiarism.

For more details consult the KNH- UoN ERC website **http://www.erc.uonbi.ac.ke**

Protect to discover

Yours sincerely,

PROF M. L. CHINDIA
SECRETARY, KNH-UoN ERC

c.c. The Principal, College of Health Sciences, UoN
The Deputy Director, CS, KNH
The Assistant Director, Health information, KNH
The Chairperson, KNH- UoN ERC
The Dean, School of Dental Sciences, UoN
The Chair, Dept.of Paediatric Dentistry and Orthodontics, UoN
Supervisors: Prof. Gladys N. Opinya, Dr.Lincoln Imbugwa Khasakhala, Dr.Richard Owino

APPENDIX 8: PLAGIARISM REPORT

INDUSWE DISSERTATION defended 22-11-2019 chek pla.doc

GRADEMARK REPORT

FINAL GRADE

9 /0

GENERAL COMMENTS

Instructor

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THE RELATIONSHIP OF DENTAL FLUOROSIS, INTELLECTUAL EFFICIENCY AND WORKING MEMORY IN 12-15-YEAR-OLDS LIVING IN LOW, MEDIUM AND HIGH-WATER FLUORIDE AREAS IN KAJIADO COUNTY

[illegible] INDUSWE BENJAMIN (BDS, UoN)

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT FOR THE AWARD OF A MASTERS DEGREE IN PAEDIATRIC DENTISTRY, UNIVERSITY OF NAIROBI

APPENDIX 9: CERTIFICATE OF CORRECTIONS

CONTENT OF CERTIFICATE OF CORRECTION

1.Name of Candidate Dr. Benjamin Induswe	**2. Registration Number** V60/82954/2015	**3. Title of Proposal** 'The Relationship of Dental Flourosis, Intellectual Efficiency and Working Memory in 13 to 15 Year Olds Living in Low and High Water Fluoride Areas in Kajiado County'
4. Name of Degree: Master of Dental Surgery (MDS) Paediatric Dentistry	**5. Date of Examination** August 8, 2019	
6. Recommendations of Board of Examiners The board of examiners considered the reports from the examiners and oral examination and recommended that Dr. Induswe Benjamin V60/82954/15 MDS dissertation is adequate and reflects a sound understanding of the subject for the award of MDS Paediatric Dentistry. Correction effected as soon as possible under supervision of Dr. Lincoln Khasakhala.		
7. Comments by supervisor by the Board Dr. Khasakhala	**8. Recommended action** Award of The Degree	**9. Signature:** Date: 22/11/19
10. Comments by Chairman of the Board of Examiners Dr. Regina J. Mutave Dean, School of Dental Sciences	**Recommended**	**Signature:** **Date:**

APPENDIX 10: DECLARATION OF ORIGINALITY

UNIVERSITY OF NAIROBI

Declaration of Originality Form

This form must be completed and signed for all works submitted to the University for examination.

Name of Student ____________________

Registration Number ____________________

College ____________________

Faculty/School/Institute ____________________

Department ____________________

Course Name ____________________

Title of the work

____

____

DECLARATION

1. I understand what Plagiarism is and I am aware of the University's policy in this regard
2. I declare that this ____________ (Thesis, project, essay, assignment, paper, report, etc) is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work, or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.
3. I have not sought or used the services of any professional agencies to produce this work
4. I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her own work
5. I understand that any false claim in respect of this work shall result in disciplinary action, in accordance with University Plagiarism Policy.

Signature ____________________

Date ____________________