FACTORS INFLUENCING THE USE OF DEFLOURIDATED WATER IN NAKURU TOWN: A CASE STUDY OF CATHOLIC DIOCESE OF NAKURU WATER QUALITY PROGRAM

BY

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DECLARATION

This is my original work and has not been submitted for the award of any degree or diploma at any other institution.

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L50/78526/2009

APPROVAL

This project report has been submitted for examination with my approval as University supervisor

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DEDICATION

I would like to dedicate this project to my family. My husband Joel Mbute, My children Alexis and Krista.

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I wish to thank my supervisor, Dr. Gilbert Obwoyere who guided me through this study, for the valuable advice he gave me in completing this document. I would like to also thank Mr. Joseph Mungai, the resident lecturer and Mr. Edward Otieno of the Nakuru Extramural Centre for their support.

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ABBREVIATIONS AND ACRONYMS

AAS:	Atomic Absorption Spectrophotometer
CBO:	Community Based Organisation
CDN:	Catholic diocese of Nakuru
CP:	Contact Precipitation
FBO:	Faith Bases Organisation
GDC:	Geothermal Development Company
NGO:	Non Governmental Organisation
O&M:	Operation and maintenance
PPM:	Parts Per Million
WHO:	World health organisation
WQP:	Water Quality Programme

ABSTRACT

The purpose of the study was to assess the contribution of the CDN water quality programme in providing safe fluoride free drinking water to the residents of Nakuru municipality. The objectives of the study were: to establish the extent to which the level of awareness influences the use of deflouridated water, to determine the influence of personal characteristics on use of deflouridated water and lastly, to determine the extent to which the method of deflouridation influences the use of deflouridated water. The study evaluated the performance of the program since its inception to date. It sought to establish if the short term goals have been realised. The research study was conducted in Nakuru Town. The study assessed the contribution of the CDN water quality programme in providing safe fluoride free drinking water to the residents of Nakuru Town. To evaluate level of awareness, an exploratory survey was conducted in the project area. Residents were randomly selected to fill the questionnaires. Three categories based on population density within the municipality were used in the survey. In order to evaluate the effectiveness of the defluoridation program the study employed an experimental design. The CDN provided a list and contacts of the people who they supplied with the buckets. 30 among them were randomly selected to participate in the survey. Study subjects were randomly selected. The provided participants in the project were assigned numbers and a sample of 30 drawn through a ballot. Each objective was analyzed using appropriate statistical tests on using frequencies, percentage, means, mean difference and t-test. This study established if the program has been able to achieve the provision of deflouridated water to the residents. This acted as an indicator in the incidences of flourosis in the target population. The major findings were that the CDN project has been able to provide an effective method of deflouridation of drinking water. However, they have been unable to increase awareness on flourosis and the program. Therefore, the recommendations are that the CDN should embark on an aggressive campaign to increase awareness on flourosis and the their products

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Water is frequently referred to as a universal solvent, because it has the ability to dissolve almost all substances that come in its contact. Some elements are essential in trace amount for human being while higher concentration of the same can cause toxic effects. Fluoride is one of them (Bardsen, 1995) Due to rapid urbanization and growth of modern industries (anthropogenic source of fluoride) as well as geochemical dissolution of fluoride bearing minerals (natural source of fluoride), fluoride concentration is increasing in the environment including water resources.

Fluorosis is an irreversible illness that can lead to permanent damage of the teeth and bones. Ingestion of excess fluoride, most commonly in drinking-water, can cause fluorosis which affects the teeth and bones. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems. Paradoxically, low levels of fluoride intake help to prevent dental caries. The control of drinking-water quality is therefore critical in preventing fluorosis, the condition and its effect on people (Largent, 2010)

Fluorosis is caused by excessive intake of fluoride. The dental effects of fluorosis develop much earlier than the skeletal effects in people exposed to large amounts of fluoride. Clinical dental fluorosis is characterized by staining and pitting of the teeth. In more severe cases all the enamel may be damaged. (Awadia et al 1997)

However, fluoride may not be the only cause of dental enamel defects. Enamel opacities similar to dental fluorosis are associated with other conditions, such as malnutrition with deficiency of vitamins D and A or a low protein-energy diet. Ingestion of fluoride after six years of age will not cause dental fluorosis (Largent 2010)

The high concentration in the drinking water leads to destruction of enamel of teeth and causes a number of conditions referred to collectively as fluorosis (Eagers, 1969). The problem of high fluoride in groundwater has now become one of the most important toxicological and geo environmental issues in India. During the last three decades high fluoride concentration in water resources resulting in the disease called "Fluorosis" is being highlighted considerably throughout the world. Over the years rapid strides have been made in India to mould the availability of water to match country's manifold potable water demand. It is a conclusive fact that concentration between 0.6 to1.2 mg/L is essential to protect teeth decay, while higher concentration (beyond 1.5 mg/L) can cause teeth mottling and still higher concentration of fluoride may lead to different major health hazards (Largent, 2010)

The development of defluoridation unit based on AlOOH is important for rural areas where the settlements are scattered and people rely on underground water as a source of drinking and their health is adversely affected by fluorosis. High fluoride containing groundwater is found in many parts of the world and fluorosis is endemic in at least 25 countries across the globe (Tetsuji et al, 1997). The worst affected 3 areas are the arid parts of northern China (Inner Mongolia), India, Srilanka, African countries like Ghana, Ivory Coast, Senegal, North Algeria, Kenya, Uganda, Tanzania, Ethiopia, northern Mexico and central Argentina. According to estimates of UNESCO more than 200 million people worldwide rely on drinking water with fluoride concentrations higher than the present WHO guideline value. This shows how much it poses a serious health problem on a global scale. (UNESCO, 2007)

In Tanzania the issue of excessive fluoride levels in drinking water in some parts of the Country is well known to experts from the water, health, nutrition and agricultural sectors. Studies by various researchers have indicated that most people from Kilimanjaro, Arusha, Singida, Shinyanga, Mwanza and Mara regions drink water with fluoride levels well above the WHO drinking water quality guideline value of 1.5 mg-F/l (Awadia et al 1997). As a result, some people have developed fluorosis problems ranging from mottled teeth to crippling fluorosis. It has also been observed that the diet of the people from the fluoride regions add to the total fluoride uptake from drinking water. Kitefu village in Arusha region for instance, received water from Maji ya Chai River until 1966, which has a fluoride content of 22 mg-F/l; at the same time people from the village used salt crusts (Magadi) whose fluoride concentration varied from 2,000 to 14,000 µg-F/g-magadi for cooking purposes (Mungure 1984) also verified that 34 % of the people in Kitefu village were suffering from skeletal fluorosis and 77% from dental fluorosis.

Fluoride is wide spread in the Rift Valley regions of Ethiopia. People in several region of

the Rift valley of Ethiopia are consuming water with fluoride up to 33 mg/L (Kloos and Redda, 1999) and are exposed to varying degrees of dental and skeletal fluorosis (Reda et al.,1987). The

Ministry of Water Resources of Ethiopia specified guideline value for fluoride concentration in drinking water not to exceed 3 mg/L (MOWR, 2002).This value is beyond the guideline level set by WHO.

1.2 Statement of the problem

Flourosis is a major problem affecting Kenyans today. Several governmental and nongovernmental organisations have undertaken measures to try and curb the problem. One organisation based in Nakuru known as the Catholic Diocese of Nakuru (CDN) has a water quality programme that seeks to provide safe deflouridated water to residents of Nakuru and its environs. This study evaluated whether the organisation has been able to achieve its objectives.

The prevalence of dental and skeletal fluorosis is not entirely clear. It is believed that fluorosis affects millions of people around the world, but as regards dental fluorosis the very mild or mild forms are the most frequent (Bregnhoj, 1997)

Removal of excessive fluoride from drinking water is difficult and expensive. The preferred option is to find a supply of safe drinking-water with safe fluoride levels. Where access to safe water is already limited, de-fluoridation may be the only solution. Methods include: use of bone charcoal, contact precipitation, use of Nalgonda or activated alumina. Since all methods produce a sludge with very high concentration of fluoride that has to be disposed of, only water for drinking and cooking purposes should be treated, (Bregnhoj, 1997)

The Catholic Diocese of Nakuru (CDN) water quality program in Nakuru Municipality employs the use of the bone char method for deflouridation. This method uses raw materials that are locally available. Animal bones are burnt in a furnace at temperatures of 500^0C so as to remove all the organic matter leaving a porous structure of calcium and phosphate which absorbs fluoride from water. These "bone char" are then crushed and graded in different sizes which are then used as a filter material.

The Water Quality Program has developed 3 types of filters suitable for different localities and users (household filters, community filters and institutional filters). Currently the program is implementing a new type of "self-regenerating" filter which increases the capacity of the bone char. The program has researched and developed pellets made up of Calcium and Phosphate which when combined with bone char increases the lifespan of the filters.

(www.cdnwaterquality.co.ke (2009). This study evaluated the effectiveness of water deflouridation process using bone char in Nakuru Municipality.

1.3 Objectives of the Study

The purpose of the study was to assess the contribution of the CDN water quality programme in providing safe fluoride free drinking water to the residents of Nakuru municipality. The objectives of the study were:

i. To establish the extent to which the level of awareness influences the use of deflouridated water.

ii. To determine the influence of personal characteristics on the use of deflouridated water.

iii. To determine the extent to which the method of deflouridation influences the use of deflouridated water.

1.4 Research Questions

The study was guided by the following research questions:

i. Are the residents of Nakuru Municipality aware of flourosis and the CDN water quality programme?

ii. How do personal characteristics influence the use of deflouridated water?

iii. To what extent does the method of deflouridation influence the use of deflouridated water?

1.5 Significance of the study

This study established that the program has been able to achieve the provision of deflouridated water to the residents. This acted as an indicator in the incidences of flourosis in the target population.

In CDN achieving its objectives, it created awareness on flourosis and how to prevent it, thus reducing incidences of flourosis which lead to better dental health. This helped in achieving the universal health care for all as provided for in the Constitution of Kenya and Vision 2030.

Furthermore, the finding of this study may be used by policy makers in Nakuru Town to improve their water service delivery.

The findings of the study also helped the CDN to have an independent external evaluation of their program which may help them to improve on it should they act on the recommendations.

1.6 Limitations and delimitations of the study

1.6.1 Limitations of the Study

The following were the limitations of the study; the researcher was not able to get all the relevant data from when the programme was began. Nakuru Town was chosen as a case study area. The study did not cover all the households in the Town or the whole Province but this was not possible due to limited resources and time. However, the researcher spent a great deal of time within the study period to collect adequate data for the study by making sure the minimum acceptable sample size for an experiment (30) households was used. The researcher also took over ten sample per house hold, this helped in validation of the results. Furthermore, some respondents withheld some useful information especially on their level of income. This limitation was overcome by assuring them that the investigation's findings shall be kept confidential.

1.6.2 Delimitations of the Study

The research only investigated the research problem based on one District in the Rift valley Province yet the CDN is operational in other Districts including Baringo, Koibatek and Naivasha. The study focused on assessing the contribution of the CDN water quality program in providing safe fluoride free drinking water to the residents of Nakuru Town. The Study population was limited to Nakuru Town. Three sub-categories based on population density and social economic statuses were chosen. The three estates from which the study was conducted were; Shabab estate, Milimani estate and Ponda Mali estate. The findings therefore did not reflect the effectiveness of the program in the other areas of operation.

1.7 Assumptions of the Study

The study assumed that the programme has been able to increase the awareness of residents on fluorosis. It will also assume that the programme has been able to supply clean drinking water to the residents and finally the programme has been able to supply appropriate and affordable defluoridation technology to the residents.

1.8 Definition of Significant Terms

Bone char: is bone that has been heated to burn away all organic impurities and then crushed to form a granular substance

Calcination: is a thermal treatment process in presence of air to ores and other solid materials to bring about a thermal decomposition.

Contact precipitation: is any product of the condensation of atmospheric water vapor that is deposited on the earth's surface.

Deflouridation: refers to methods of water treatment that reduce the concentration of fluoride in the water, normally, in order to make it safe for human consumption.

Fluorosis: is a developmental disturbance of dental enamel caused by excessive exposure to high concentrations of fluoride during tooth development.

Sludge: is a thick, soft mud or a similar viscous mixture of liquid and solid components, especially the product of industrial or refining process.

1.9 Organization of the study

This research was organized in the following manner: Chapter one dealt with the preliminaries from dedication, acknowledgements, abstract, background of the study and statement of the problem, the objectives and research questions, significance of the study, limitations and delimitations of the study and finally, the operational definition of significant terms. Chapter two dealt with the review of Literature based on a discussion of the objectives and Theoretical framework based on the coercion Theory and finally on the Operational definition of variables.

Chapter three dealt with the methodology for the research from the design, target population, sampling size and selection, research instruments, validity and reliability of instruments, data collection procedure and ethical considerations for the research.

Chapter four dealt with data analysis, interpretation and discussion of findings from both the questionnaires and the experimental data.

Chapter five dealt with discussion of findings, conclusions and recommendations based on the results of the research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter dealt with review of related literature for the study. The literature review was organized as follows: theoretical review, empirical review, history of defluoridation, methods of defluoridation, physical properties of bones calcined at different temperatures, other defluoridation options, alternatives to defluoridation, various health impacts of fluoride, prevention and control and defluoridation of water.

Chronic high-level exposure to fluoride can lead to skeletal fluorosis. In skeletal fluorosis, fluoride accumulates in the bone progressively over many years. The early symptoms of skeletal fluorosis include stiffness and pain in the joints. In severe cases, the bone structure may change and ligaments may calcify, with resulting impairment of muscles and pain. Acute high-level exposure to fluoride causes immediate effects of abdominal pain, excessive saliva, nausea and vomiting. Seizures and muscle spasms may also occur (Mkongo, 1995)

Acute high-level exposure to fluoride is rare and usually due to accidental contamination of drinking-water or due to fires or explosions. Moderate-level chronic exposure (above 1.5 mg/litre of water - the WHO guideline value for fluoride in water) is more common. People affected by fluorosis are often exposed to multiple sources of fluoride, such as in food, water, air (due to gaseous industrial waste), and excessive use of toothpaste. However, drinking water is typically the most significant source. A person's diets, general state of health as well as the body’s ability to dispose of fluoride all affect how the exposure to fluoride manifests itself (Mkongo, 1995)

Distribution of Flouride

Fluoride in water is mostly of geological origin. Waters with high levels of fluoride content are mostly found at the foot of high mountains and in areas where the sea has made geological deposits. Known fluoride belts on land include: one that stretches from Syria through Jordan, Egypt, Libya, Algeria, Sudan and Kenya, and another that stretches from Turkey through Iraq, Iran, Afghanistan, India, northern Thailand and China. There are similar belts in the Americas and Japan. In these areas fluorosis has been reported (Chikte, 1997).

Distribution of Dental Flourosis in Kenya

Dental fluorosis has been known to be endemic to Kenya for many years (Akpabio, 1970; Bakshi, 1974; Bohdal et al., 1968; Munoz et al., 1964; Nair & Manji, 1982; Neville & Bras, 1953; Ockerse, 1953; Ongweny, 1973) and is considered today as one of the major dental public health problems of Kenya. Dental fluorosis is associated with the ingestion of high levels of fluoride ion in the diet (Dean,1936), and in Kenya the major source of the ion is thought to be from drinking water, especially in those regions of the country associated with volcanic rocks and hot springs (Williamson, 1953).Other important sources of fluoride have been identified and these include foods and drinks (Gitonga & Nair, 1982), as well as dust in some of the lake regions; for example, around Lake Nakuru the dust has been shown to have concentrations of fluoride of between 2800 and 5600 ppm (Williamson, 1953).

The majority of Kenya's rainfall, at least that part of it which does not evaporate, passes through the surface soil and is stored underground. Groundwater is thought to form the major sources of water for the majority of Kenya's population. Though the country is well supplied with numerous rivers and streams, the majority contain water only during the rainy seasons (Ojany, 1974). In Kenya, the only form of treatment carried out on ground water is chlorination for urban supplies, and no treatment is provided for rural water supplies with boreholes as a source.

The first attempt to study the occurrence and distribution of fluoride ion concentrations in ground waters of Kenya was probably by Williamson (1953) .The study examined results available from analyses carried out by the Government Chemist of fluoride levels in borehole waters. The spatial distribution of some 200 boreholes was plotted on a map of the country, indicating that many parts of Kenya suffered from excessively high levels of fluoride. In some areas extremely high levels of fluoride ion concentrations were reported - for example the highest levels in wells was 39.0 ppm in boreholes, 43.50 ppm, in Lake Elementaita 1640 ppm and in Lake Nakuru 2800 ppm.

Their findings for the Rift-valley province in which the CDN project is operational are summarized in the table below.

Table.2.1 Number of groundwater samples in each district in Rift valley containing various levels of fluoride (in ppm)

RIFT VALLEY PROVINCE

District	Level of fluoride in ppm from 6 water samples from each districts						Total
Baringo	1	1	1	-	-	1	4
Elgeyo Marakwet	1	1	-	-	-	-	2
Kajiado	10	12	32	9	1	2	66
Kericho	-	5	1	4	-	1	11
Laikipia	1	6	14	4	2	1	28
Nakuru	11	10	50	26	18	24	139
Narok	1	1	3	-	-	1	6
Samburu	-	2	8	-	1	-	11
Trans Nzoia	2	2	1	-	-	-	5
Turkana	9	5	6	-	1	-	21
Uasin Gishu	8	4	5	-	2	1	20
Nandi		-	-	-	-	-	-

Source: (Williamson, 1953)

2.1.2 Dental flourosis

Dental fluorosis is the loss of luster and shine of the dental enamel. The discoloration starts from white yellow, brown to black. (Discoloration is either as spots or horizontal streaks). Enamel matrix is laid down on incremental lines before and after birth. Hence dental fluorosis is invariably seen on horizontal lines or on bands on the surface of the teeth.

Fluorosis is seen as mild moderate and severe depending on the amount of fluoride ingested during the stages of formation of the teeth. Teeth commonly affected by fluorosis are central incisors, lateral incisors and the molars of the permanent dentition. It affects both the inner and the outer surfaces of teeth.

The symptoms of dental fluorosis are as given below: Dullness of the teeth and loss of shine with developed white and yellow spots. Discoloration of teeth, turning into brown and black streaks or spots on the enamel surface.

Incidences of mottled teeth have been observed even with range of 0.7 – 1.5 mg F / l in drinking water (Dean, 1936). The minimal daily intake of fluoride that can cause very mild or mild fluorosis is estimated to be about 0.1 mg/kg body weight (Fawell, 2006).

2.1.3 Loss of teeth at early age

The teeth, once affected by dental fluorosis, cannot be reversed to normal. Only discolored teeth can be masked by bleaching of teeth, filling with high cure material and laminated veneering and capping or crowning of teeth with metals like chrome, cobalt, gold, porcelain and acrylic (Rajchagool, 1997)

2.1.4 Skeletal fluorosis

Excessive quantity of fluoride deposited in the skeleton, which is more in cancellous bone than cortical bone .Fluoride poisoning leads to severe pain associated with rigidity and restricted movements of cervical and lumbar spine , knee and pelvic joints as well as shoulder joints . In severe cases of fluorosis, there is complete rigidity of the joints resulting in stiff spine described as “bamboo spine”, and immobile knee, pelvic and shoulder joints. Crippling deformity is associated with rigidity of joints and includes kyphosis, scoliosis, flexion deformity of knee joints, paraplegia and quadriplegia (Mkongo F J, 1995)

2.1.5 Drug induced fluorosis

The prolonged use of drugs containing sodium fluoride is known to cause skeletal fluorosis. During 1982, two cases of drug induced skeletal fluorosis were reported from Switzerland. Patients of rheumatoid arthritis received uninterrupted and prolonged treatment with niflumic acid. The daily dose of drug administered was 3 capsules of 250 mg niflumic acid (Nifluril, UPSA Laboratories, France. Fluoridated toothpastes and mouth rinses recommended for mouth hygiene may cause drug induced fluorosis, particularly if the user is exposed to high fluoride water consumption. The blood vessels in the oral mucosa and the sublingual blood vessel absorb fluoride from these preparations. The commercial mouth rinses are generally fluoridated preparations with very high fluoride content (Sharma and Parul 2009)

2.1.6 Industrial fluorosis

A number of industries use hydrofluoric acid and fluoride containing salts in the different sections of an industry for one reason or other. The industries that use fluoride are; 1) Aluminium 2) Steel 3) Enamel 4) Pottery 5) Glass 6) Bricks 7) Phosphate Fertilizer 8) Welding 9) Refrigeration 10) Rust Removal 11) Oil Refinery 12) Plastic 13) Pharmaceutical 14) Tooth paste 15) Chemical Industries 16) Automobile Industry ((Fawell, et al., 2006)

2.1.7 Prevention and control

Fluoride poisoning can be prevented or minimized by using alternative water sources, by removing excessive fluoride from drinking water, and by improving the nutritional status of populations at risk.

2.1.8 Alternative water sources:

These include surface water, rainwater, and low-fluoride groundwater.

Surface water:

Particular caution is required when opting for surface water, since it is often heavily contaminated with biological and chemical pollutants. Surface water should not be used for drinking without treatment and disinfection (Gupta, Seth and Gavane, 1993). Many water treatment technologies are available, but the most effective are usually too expensive and complex for application in poor communities. Simple and low-cost technologies, such as sand filtration, ultraviolet water disinfection or chlorine water disinfection, are adequate in some but not all cases. Community capacity is an essential factor in ensuring successful utilization of these technologies. Water chlorination at household level is widely used only in emergencies.

Rainwater

Rainwater is usually a much cleaner water source and may provide a low-cost simple solution. The problem, however, is limited storage capacity in communities or households. Large storage reservoirs are needed because annual rainfall is extremely uneven in tropical and subtropical regions (Chinoy, 1991). Such reservoirs are expensive to build and require large amounts of space.

Low-fluoride groundwater:

Fluoride content can vary greatly in wells in the same area, depending on the geological structure of the aquifer and the depth at which water is drawn. Deepening tube wells or sinking new wells in another site may solve the problem. The fact that fluoride is unevenly distributed in ground water, both vertically and horizontally, means that every well has to be tested individually for fluoride in areas endemic for fluorosis: extrapolating sample tube well tests to a larger area does not provide an accurate picture (Gupta, Seth and Gavane, 1993).

2.2 Empirical review:

2.2.1 History of Defluoridation

The problem of fluorosis is nothing new as fluoride is naturally occurring in ground water. Fluoride has been one of the most widespread endemic health problems associated with natural geochemistry." Indeed, ancient skeletal remains in fluorotic areas exhibit signs of fluorosis.

Though an ancient problem, there were little formal attempts to defluoridate water before the 20th century. The problem of fluorosis was not necessarily identified until recent history. Some of the earliest diagnoses of dental fluorosis come from 1888 in Mexico and 1891 in Italy (Fawell, et al, 2006). Still the link between drinking water and fluorosis wasn’t established until the 1920s in Colorado, by dentist Dr. Fedrick S. McKay. As many parts of the world where fluorosis is common are relatively isolated, many cultures in fluorotic regions never considered dental fluorosis to be an abnormality until increased communication and travel resulted in changes in perception

Additionally, skeletal fluorosis can often take an extended time to develop visible symptoms, so it is not necessarily obvious for people to link fluorosis to a problem in water quality. It was in the 1930s that several nations first began to more seriously investigate the negative effects of fluoride and how to remove it from drinking water supplies (Meklau, 1997).

2.3 Methods of Defluoridation

Several methods have been developed to reduce fluoride from contaminated water but the

most common defluoridation methods used in developing countries at present are Sorption on activated alumina, co-precipitation with aluminium hydroxide (known as the Nalgonda Technique) and sorption on bone char (Muller et al 2006). Recently, heat treated aluminium hydroxide, Al (OH)3 at 300 ^{0}C known as aluminium oxide hydroxide (AlOOH) has shown high adsorption capacity both in batch and packed bed continuous systems in the lab scale as compared to activated alumina (Beneberu et al.,2006, Feleke et al.,2008). This AlOOH sorbent can be produced locally from hydrated aluminium sulfate (alum) in order to use it in household treatment units

As with the treatment of other chemical contaminants, such as arsenic, fluoride cannot be removed by typical water treatment means. Boiling, UV treatment, most methods of filtration, and most chemical treatment options do nothing to remove fluoride concentrations from water. Synthetic ion exchange and precipitation processes, activated alumina filters, and reverse osmosis are typically used to remove fluoride from water in the developed world (Shaw, 1954), there are no universally accepted or routinely used defluoridation techniques in the developing world. Thus, defluoridation is a prime example of field in the need for further development of appropriate technologies. Ultimately social, financial, cultural, and environmental factors must all be weighed to determine what solutions should be implemented in a region.

It must be noted that most of the defluoridation methods discussed here are point-of-use (POU) treatment options. These options are preferred for defluoridation in developing world settings. Though many POU treatments are done so to help reduce the risk of recontamination of water, defluoridation techniques, however, are typically POU because it helps to reduce costs. Because only water needed for drinking and cooking (about 25% of total water usage) needs to be treated, municipal level treatment is rare.

Still in some places a community scale defluoridation plan can be more appropriate. As with other methods of water treatment, the economics of the situation must be weighed to determine what scale is most appropriate.

2.3.1 Nalgonda technique

The Nalgonda technique was developed by the National Environment Engineering Research Institute (NEERI) in Nagpur (India) in the 1960s and has since mainly been implemented in India. The process involves adding aluminium sulphate and lime to raw water.

The addition of aluminium sulphate to raw water results in the creation of insoluble aluminium hydroxide flocs (Müller et al., 2006). Then, by the processes of coagulation/flocculation and sedimentation, part of the initial fluorine concentration can be removed from the water as a solid. The addition of lime ensures an optimal removal pH of around 6-7 (Dahi et al., 1996), which allows the complete precipitation of aluminium (WHO, 2006). The second effect of the lime is to help to form dense flocs for rapid settling (Gupta & Deshpande, 1998).

The reactions involved in this process are (WHO, 2006):

Aluminium dissolution	$Al_2(SO_4)318H_20 \leftrightarrow 2Al_3++ 3SO_42-+ 18H_20$
Aluminium precipitation	$2Al_3++ 6H_20 \leftrightarrow 2Al(OH_3) + 6H+$
Co-precipitation	$F-+ Al(OH)_3 \leftrightarrow$ Al-F complex + undefined product
pH adjustment	$6Ca(OH)_2+ 12H+ \leftrightarrow 6Ca_2+ + 12H_2O$

The dose of each reagent can be determined by jar testing or by using tables developed by the NEERI (Nawalkhe et al., 1975 and Gupta & Deshpande, 1998), in which the amount of aluminium sulphate is given according to the alkalinity of the water and the fluorine concentration in the raw water. Concerning the amount of lime needed, (Nawlakhe et al,. 1975) recommends using a concentration equal to one twentieth of the aluminium sulphate concentration.

The limit of the efficiency of this technique, defined by the maximum concentration of fluorine in the raw water which is possible to be removed in order to meet the WHO Standard, is not made clear in the literature.

In order to achieve 1.5 mg/l of fluorine in the treated water, a value of 20 mg/l of fluorine in the raw water is predominantly cited (Banuchandra & Selvapathy, 2005) although a value of 10 mg/l (Müller et al., 2006 and Mjengera & Mkongo, 2002) is also found.

The Nalgonda technique can be implemented at a household level with the use of a bucket or at community level with a tank. In the Nalgonda technique at household level, adapted from WHO, The treatment steps at a household level are addition of the chemicals to the raw water, fast mixing, slow mixing, settling. The periods of time for the last three steps differ from one author to the next. Generally, the fast mixing is a period around one minute (Bjarne, 1996 and Dahi et al., 1996), the slow mixing varies from five (Dahi et al., 1996) to twenty minutes (Gupta & Deshpande, 1998) and the settling lasts one hour (Nawlakhe et al., 1975).

According to Müller et al. (2006), the limitations of this technique are the risk of contamination of the treated water by aluminium in case of over-dosing of aluminium sulphate. The WHO Standard concerning aluminium is 0.2 mg/l, which is very low, the fact that this is a work-intensive method, especially at a household level due to the need of daily mixing for around fifteen minutes. Moreover, the WHO (2006) notes that the sludge produced by this process is quite toxic. Precautions concerning the storage and disposal of the sludge are then required, in term of location and access.

2.3.2. Activated Alumina

Activated alumina is just what it sounds like, Alumina (Al_2O_3) that has been activated to become adsorptive. The method of activation is done through dehydration of aluminum hydroxides at temperatures of 300-600^oC (Fawell et al., 2006).

An extremely effective technology, activated alumina has been used in defluoridation since 1936 and was first used on a large scale in South Africa in the 1980s.

Though it is often used for large scale defluoridation in the developed world, activated alumina has long been considered to not be an appropriate technology for use in the developing world because of chemical costs and availability. This technology is recently being reconsidered and is considered economically feasible for many in China, India, and Thailand. This is probably due to higher level of infrastructure established in these countries needed to produce activated alumina. Still, costs prevent activated alumina from taking off in much of the developing world. However, the exploration of lower cost methods of producing activated alumina, as has been developed in one study Vietnam, may result in this technology becoming more accessible to more people.

Activated alumina is used in an adsorption process with very high fluoride removal efficiency (able to treat water with fluoride concentrations from 4-20mg/L). Though it has been used successfully to treat water for a number of contaminants, it has the advantage of having a very high selectivity for fluoride. The theoretical defluoridation capacity of the material increases with lower pHs (as high as 20.4 mg F/g at pH of 3), with any pH less than 9 resulting in a positive charge on the alumina surface that adsorbs the fluoride ions ((Fawell, et al., 2006)

2.3.3 Bone Char

Bone char is the oldest known technology for water defluoridation, being successfully used since the 1940s. It has been utilized successfully for at least 5 decades and was at one point used heavily in the United States for municipal water defluoridation and sugar refining. Bone char has also been used successfully in the removal of arsenic from water. Bone char is produced with animal bones that have passed through calcination or pyrolysis processes.

Though raw bones have some defluoridation value, it is small and limited by the various organics obstructing the interfaces where chemical reactions with the fluoride take place (Fawell, et al., 2006). In order to produce bone char, animal bones must first be collected. These bones can be collected from a variety of sources including butchers, restaurants, ranchers, etc. This can create an entirely new market by giving value to what was previously viewed primarily as a waste material.

Bone Collection

Once the bones are collected, they are often washed, rinsed, boiled, or sun dried to remove much of the organics before they are actually charred to be used as filter media. Many different animal bones can work, as the uptake of fluoride hinges upon a reaction with hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$), a mineral found in all bones. One study showed that there is slight variability seen in the capacity of char made from different animals, with cows and pigs yielding char with more capacity than chicken and fish, but the differences are often regarded as minor. There can be significant cultural reasons to select one animal bone type over another. Bone char made from cattle may be a problematic for Hindus, char made from pigs may not be accepted by Muslim and Jewish communities, and char from dogs and hyenas may be rejected in many African communities.

Shaw (1954) points out that calcination is the process of subjecting the bones to high temperatures (300-700^{o}C) with atmospheric oxygen present (Gupta & Deshpande, 1998). This results in a bone char product that is chiefly just hydroxyapatite with the organics burning off as CO_2. Hydroxyapatite is the primary mineral component of bones and the mineral in which an ion exchange with fluoride takes place. There is significant variability is the quality of calcined bone char in terms of fluoride uptake.

Pyrolytic bone char is bone char that has been charred in the absence of oxygen. Though potentially more complicated to produced, it has proven to be much more desirable than calcined bone char. Rather than burning the organic materials, pyrolysis results in the conversion of organic materials into a usable activated carbon, which can treat the water beyond fluoride. (Fawell, et al., 2006) A well done batch of pyrolytic bone char should result in about 10% activated carbon with the rest chiefly being hydroxyapatite for the fluoride ion exchange process. The quality of pyrolytic bone char is far less variable than that which has been calcined. Additionally, it loses less mass (31% as opposed to the 38% of mass lost in calcination) and capacity through the charring process.

The difference between pyrolytic and calcined bone char is not necessarily black and white. Pure pyrolysis results in black bone char will be most likely due to the increased amount of graphite (activated carbon) that is present, while calcination can vary in color form white to dark grey (Karthikeyan, 1997). As implied, generally the closer the charring process is to pure pyrolysis the better. Not only does this result in higher quality bone char in terms of fluoride removal capacity, but in terms of activated carbon present as well.

Physical Properties of Bones Calcined at Different Temperatures

The amount of time the charring is done can vary significantly depending on the quantity of bones being charred and the desired quality. Typically the total charring time is a matter of days, with perhaps a few hours actually at the maximum temperature because it takes a long time to heat up the massive furnaces. Once charred, the bones are then crushed and sieved to achieve desired sizes. As with the temperature there are variations in what is considered to be the optimal grain size for bone char use in defluoridation. Most sources agree that the use of 0.5-4 mm diameter grains can and should be used with both effectiveness and economics in mind. It has actually been shown that the grain size has no bearing on the dynamic capacity of the bone char, but rather it is the reaction rate that is affected. The reaction rate constant is nearly reciprocal of the grain diameter. That is, smaller diameters result in quicker reactions. Too small of a grain size can result in too much head loss when the char is used as a filter media, so care must be taken to ensure that the grain sizes of the media are not so small as to clog the filter.

As mentioned, the crushed bone char is then used as a filter media. Typically bone char filters are designed as gravity-fed column filters, though there have been a few different configurations implemented: Bucket Filter, Drum Filter and Column Filter

The primary difference exists between the first two filters and the column filter. The column filters more closely resembles a plug flow reactor, while the other two have more of a mixed flow (Chikte, 1997). Thus, the column filters generally make more efficient use of the filter media. In order to estimate the life of filter media when designing a filter the operational defluoridation capacity of a filter is estimated from the theoretical defluoridation capacity. The theoretical capacity is calculated based on scaling up the amount of fluoride that each grain of bone char can hold. A proposed rule of thumb is that the closer a filter is to being a column filter (and therefore a plug flow reactor) the operational defluoridation capacity is 2/3 the theoretical defluoridation capacity (Typical capacity of 2-6 mg F/g for bone chart), while the bucket and drum filters have a operational defluoridation capacity closer to 1/3 the theoretical defluoridation capacity. There are a number of design parameters critical in the construction of a bone char filter.

The primary advantages to making a bucket or drum filter all lie in the filter construction. Because the filter unit themselves can be made from a wide variety of materials, it is often far easier to use cheap and readily available containers to make filters, rather than the custom manufacturing of a column filter (Karthikeyan, 1997). It is recommended that bone char filters be rinsed through a few times before they are actually used as there may be some residual organic materials in the char that may negatively affect the taste of the water. Though this should not be a concern if the charring process was done well (Fawell, et al., 2006). (Pyrolytic bone char yields no odors or unpleasant taste. Due to variations in the charring process, the actual chemical composition of bone char can vary slightly. Other deflouridation options include; reverse osmosis, use of synthetic materials, solar distillation, and biological options, (Mariappan, & Vasudevan, 2002 Karthikeyan & Shunmuga, 2002)

2.3.4 Alternatives to Defluoridation

Of course there are a number of ways to help reduce the occurrences of fluorosis other than just treating water. All of the water resource options available should be assessed economically, as it may be more affordable to find and use a different water source. (Often times water source should just be abandoned rather than treated, especially if it has exceptionally high levels of fluoride.) Rainwater often can provide a fluoride free water source (Fawell, et al., 2006), though this isn't universally agreed upon. Sometimes if multiple water sources are available, the source with lower fluoride concentrations can be used to dilute the fluoride concentration of another (Chikte, 1997).

Additionally, diet can play a significant role in the effects fluorosis has on the body. A diet that is high in protein, vitamin C, calcium can help reduce the effects of fluorosis. That being said, milk consumption should be encouraged (Jerry, et al., 2006). On the other side, general malnourishment generally exacerbates the harmful effects of fluoride and a diet that is high in silicon, a mineral critical in bone mineralization, also has been shown to make the effects of fluorosis worse.

2.3.5 Health Impacts of Fluoride

Fluoride inhibits enzymes that breed acid-producing oral bacteria whose acid eats away tooth enamel. This observation is valid, but some scientists now believe that the harmful impact of fluoride on other useful enzymes far outweighs the beneficial effect on caries prevention. Fluoride ions bind with calcium ions, strengthening tooth enamel as it forms in children. Many researchers now consider this more of an assumption than fact, because of conflicting evidence from studies in India and several other countries over the past 10 to 15 years. (Gupta, 1993)

Nevertheless, agreement is universal that excessive fluoride intake leads to loss of calcium from the tooth matrix, aggravating cavity formation throughout life rather than remedying it, and so causing dental fluorosis (Gupta, et al., 1993). Severe, chronic and cumulative overexposure can cause the incurable crippling of skeletal fluorosis. Fluoride being an electronegative element and having a negative charge is attracted by positively charged ions like calcium (Ca^{++}). Bone and tooth having highest amount of calcium in the body attracts the maximum amount of fluoride and is deposited as Calcium Fluoroapatite crystals. Intake of fluoride above 1.5 mg/L may lead to serious manifestations.

2.4 Theoretical Framework

Several methods have been developed to reduce fluoride from contaminated water but the

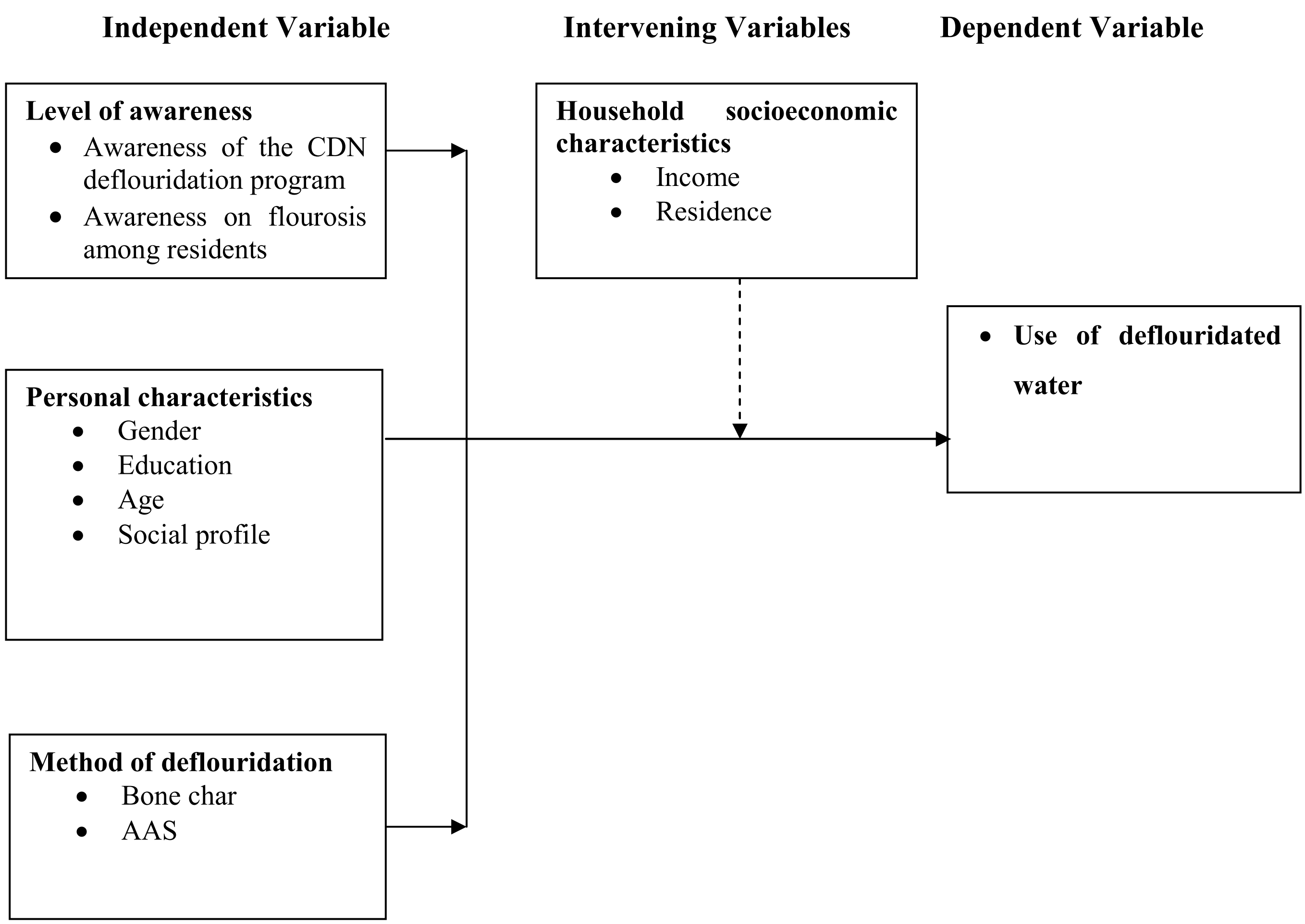
most common defluoridation methods used in developing countries at present are; Sorption on activated alumina, co-precipitation with aluminium hydroxide (known as the Nalgonda Technique) and sorption on bone char (Muller et al 2006). Recently, heat treated aluminium hydroxide, Al (OH)3 at 300 ^{0}C known as aluminium oxide hydroxide (AlOOH) has also shown high adsorption capacity.

2.5 Conceptual Framework

This study is premised on a conceptual framework (Fig 2.4.1) that shows the envisaged relationships between the independent variables; level of Fluoride in water before treatment and level of fluoride after treatment. The dependent variable being Water quality after treatment as influenced by awareness of the CDN water quality program, affordability of the technique and household socioeconomic characteristics.

It is envisaged that there could be a direct relationship between the use of bone char and effective deflouridation. However, this could be constrained by awareness of the CDN water quality program, affordability of the techniques well as the household socioeconomic characteristics

Fig 2.1 Conceptual framework



CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter described the research design, study area, target population, sample size and sampling techniques, research instruments, instruments validation, ethical considerations, data collection procedures and methods of data analysis.

3.2 Description of Study area

The study was conducted in Nakuru town for the following reasons; the CDN water project is based in Nakuru, there are known incidences of flourosis due its location in the Rift Valley which is a fluoride belt and high concentration of fluoride in both surface and underground water in Nakuru. Nakuru is located in the Great Rift Valley. The geology of Nakuru area comprises mainly of volcanic soils and rocks and this volcanic activity give rise to the high concentration of fluorides and other inorganic salts in water and soil. There is a major salt water lake called Lake Nakuru, which is situated within the National park. Another major volcanic feature is the Menengai crater which is also as a result of volcanic activity. Nakuru experiences a hot and dry climate most times of the year (Muller, K. 2007)

The population of Nakuru Town was estimated to be 309,424 as per the 2009 census which was carried out by the Kenya Population Data Networks

3.3 Research Design

The research was exploratory. It involved the use of both questionnaires and an experiment to measure the variables. The variables to be measured in experiment included; Current levels of fluoride in untreated water and levels of fluoride after treatment using bone char filters. The acceptable levels of fluoride in drinking water should not exceed 1.5mg/L (WHO, 2010)

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3.3 Experimental Layout

The experimental layout was complete randomized design (CRD). For each of the respondents, water samples were taken from their water sources before and after the defluoridation process.

3.3.1Sampling for the experiment

In order to evaluate the effectiveness of the fluoride filters, 30 users of the fluoride removal buckets were randomly chosen. Their water was obtained and tested for levels of fluoride before deflouridation, and then the levels were again tested after deflouridation.

Each respondent provided ten water samples (five before defluoridation and five after defluoridation). Each sample was 300ml. These were mixed to make a composite sample.

A final sample was obtained from the composite for each household for before defluoridation and after defluoridation for laboratory analysis. Five 300ml samples of sterile water was used as a control for the experiment. Five subsamples from the composite sample were analyzed per household and averaged to provide the fluoride levels in the drinking water before and after the deflouridation process. The levels of fluoride in the treated water were compared to WHO and Kenya Bureau of Standards recommended levels of 1.5mg/L

Table 3.1 Experimental Layout

	Fluoride levels in water samples in ppm Before defluoridation					**Fluoride levels in water samples in ppm After defluoridation**				
	1	2	3	4	5	1	2	3	4	5
Hse 1										
Hse 2										
Hse 3										
Hse 4										
Hse 5										
Hse 6										
Hse 7										
Hse 8										
Hse 30										
Control										

3.4. Measurement of fluoride levels in water samples

3.4.1 Flouride removal methods

Several methods for removal of fluoride from drinking water have been described in the literature, but only a few are used in practice. The methods differ from each other in technique, arrangement, performance and material. The process of removal of fluoride is generally termed as defluoridation or defluoridation. In this work, the removal of fluoride (F) from water solutions using a ferric poly-mineral (FPM) from Nakuru was therefore studied using batch adsorption experiments. The effect of change in solution pH, temperature, initial concentration of F, mass of FPM, contact time and presence of various competing ions on F adsorption onto FPM was evaluated(CDN, 2009)

3.4.2 Fluoride ion test

A water sample was obtained and distilled in an electrical furnace. The furnace was an Atomic Absorption Spectrophotometer (AAS210VGP) at a constant temperature (600^0C) for 15 minutes followed by cooling for 45 minutes. It was then stirred with a magnetic stirrer and tetraflouroethylene coated stirring bars. A calcium oxide reagent and phenolphthalein indicator was then added to the sample. Fluoride reference electrodes was inserted into the solution for 5 minutes and then the reading obtained in parts per million. The reading recorded indicated the level of fluoride in that water sample. If the reading was more than 1.5 parts per million (ppm), it was considered to be too high (www.merckmillipore.com/fluoride-test).

3.4.3 Laboratory Test Methods

Adsorption isotherms were then applied to the adsorption data to characterize and establish the adsorption capacity of the mineral. The adsorption of F onto FPM was found to be a fast process and, at 1000 mg/L initial F concentration at pH 3.32 and 293 K and using 0.2 mg/L adsorbent dosage, over 90% F removal from solution could be achieved in 30 min. Based on Giles system of classification of adsorption isotherms, F adsorption isotherm conformed to L4 Langmuir-type isotherms. This indicated that FPM is composed of a heterogeneous surface consisting of sites which, during adsorption, filled-up with F ions in succession. The adsorption data also correlated to Langmuirand Freundlich models indicating that F adsorption onto FPM was a mixed process involving chemisorptions onto surface sites followed by gradual intra-particle penetration of F into mesoporous structure of the mineral. High mean Langmuir adsorption capacity of 10.8 mg/g, indicate that the mineral could be of use as an inexpensive substrate for the removal of F from aqueous streams (www.merckmillipore.com/fluoride-test).

The WHO standard for acceptable levels of fluoride in drinking water is 1.5mg/L. The National standard for fluoride levels in water that is considered safe is the same as the WHO standard (1.5mg/L) (www.naturalpedia.com/flourosis.html)

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3.5 Exploratory Survey

The exploratory design used both qualitative and quantitative analysis of the research variables. The variable to be measured included; Awareness on flourosis and the CDN water program.

3.5.1 Sample Size and Sampling Procedure

According to Yamane, for populations greater than 10,000, sampling was done from 1,000 members of the group to be surveyed.

In order to evaluate the awareness on flourosis and the CDN program, and therefore using Yamane' s sample size determination formula; a sample size of 100 respondents was selected to participate in the study. The formula was presented as; (Yamane, 1967)

$$n = \frac{N}{1 + Ne^2}$$

Where

n = sample size

N= Target Population

e = error limit (0.1)

Therefore

$n = \underline{1000/}1 + 1000(0.1^2)$

= 100

The 100 respondents were stratified into three sampling sub-units. In each sub-unit, 33 respondents were selected randomly to participate in the study. The sub units were based on socio economic status and population density. These were low, medium and high population density areas

3.6 Validity and Reliability of Research Instruments

3.6.1 Validity of Research Instruments

Validity is concerned with the degree to which an empirical measure or several measures of a concept accurately represent that concept. Validity is the degree to which results obtained from analysis of the data actually represents the phenomenon under study (Mugenda & Mugenda, 2003). To test validity of the fluoride meter, a control water sample was be used. Different samples from the same source were measured to see if the results are the same. The results were constant, that was an indicator that the instrument was valid.

3.6.2 Reliability of Research Instruments

This is a measure of the degree to which a research instrument yields consistent results or data after repeated trials (Mugenda & Mugenda, 2003). This therefore means that it is the dependability or trustworthiness of the research instrument to consistently yield the same data under similar conditions. To establish the reliability of the research instruments, a pilot study was conducted in the neighboring Kiti estate believed to have the same characteristics as the study respondents. The purpose of the pilot study was to establish if the research instruments may provide the needed data and was done in Kiti to avoid the participants influencing each other and therefore interfering with the findings. The research instruments were administered to the pilot group. The results were be organized and coded for analysis. Cronbach Alpha coefficient of above 0.7 is widely acceptable as a good measure of reliability (Gay, 1992).

3.7 Data Collection Procedures

The researcher delivered the questionnaires personally and also with the help of research assistants. A period of three days was given to respondents to fill the questionnaires, after which the researcher collected them.

The experiments were conducted and analyzed by the researcher with the help of staff at the CDN laboratories who gave direction on the more technical aspects of the experiment.

3.8 Data Collection Instruments

The study collected data using questionnaires. According to Mugenda and Mugenda (2003), questionnaires are commonly used to obtain important information about the population and each item in a questionnaire addresses a specific objective and research question of the study. This tool was used because it enabled the researcher to collect data from a large number of respondents within a short period of time. The questionnaires consisted of mostly closed-ended and a few open-ended items.

The study also employed the use of an experiment using the AAS to measure actual levels of flouride in water before and after use of the buckets. The two levels were then be compared to determine the extent of fluoride removal in the water

3.9 Data Analysis

Data collected were checked and edited for correctness. Each objective was then analyzed using appropriate statistical tests. Data was analyzed with the help of SPSS. Frequencies, percentages, means and mean difference were used for analysis. The data was then presented in the form of tables and figures.

3.10 Ethical Considerations

Before proceeding to the field, the researcher sought permission from National Council for Science and Technology and approval and clearance from the university. The researcher then sought permission from Nakuru municipal council to conduct the study in the area.

The permission was sought from the respondents before data was collected from them. They were also assured of anonymity and confidentiality on any information they provided.

3.11 Operational Definition of variables

In this study the independent variables were the levels of fluoride in both treated and untreated water, extent of fluoride removal in water and management of dental flourosis while on the other hand the dependent variable was effectiveness of the deflouridation process by the CDN.

Table 3.1 Operationalisation of variables

Research Questions	Variables	Measurements	Measurement levels	Data collection	Tools of analysis
Are the residents of Nakuru Municipality aware of flourosis and the CDN water quality programme?	**Independent Variable:** Levels of awareness	-Levels of Flouride in untreated water in mg/l Flouride ion test -Education, Residence, Occupation, Age income -Level of awareness among residents using a likert scale -Cost of technique -Levels of Flouride after treatment with bone char in mg/l Flouride ion test	Ratio Interval Ratio Ratio	Questionnaire Experiment	**Means** **Frequencies** **Percentages** **Mean difference**
What is the current level of fluoride in untreated water from taps and boreholes within Nakuru Town?	**Independent Variable:** Water quality programme	-Levels of Flouride in untreated water in mg/l Flouride ion test -Education, Residence, Occupation, Age income -Level of awareness among residents using a likert scale -Cost of technique -Levels of Flouride after treatment with bone	Ratio Interval Ratio Ratio	Questionnaire Experiment	**Means** **Frequencies** **Percentages** **Mean difference**

		char in mg/l Flouride ion test			
What is the extent of fluoride removal from water using the bone char method	**Independent Variable:** The bone char method	-Levels of Flouride in untreated water in mg/l Flouride ion test -Education, Residence, Occupation, Age income -Level of awareness among residents using a likert scale -Cost of technique -Levels of Flouride after treatment with bone char in mg/l Flouride ion test	Ratio Interval Ratio Ratio	Questionnaire Experiment	**Means** **Frequencies** **Percentages** **Mean difference**

CHAPTER FOUR

DATA PRESENTATION, ANALYSES AND INTERPRETATION OF FINDINGS

4.1 Introduction

This chapter presents the study findings. As an initial motivation, simple descriptive statistics are presented then followed by means. This is aimed at assessing the nature of distributed cases in each variables as well as forming the basis for recording of variables which would in turn facilitate meaningful further analysis.

4.2 Response Return Rate

In this study, the respondents were drawn from three estates which include; Shabab, Ponda Mali and Milimani. This was also divided in three levels in order to find out which group clearly was aware of flourosis. These results are presented in the table 4.1 below.

Table 4.1: Response return rate

Estate	**Frequency**	**Percentage**
Ponda Mali	33	33
Shabab	33	33
Milimani	34	34
Total	**100**	**100**

Out of the anticipated sample size of 100 respondents, the results shows that a total of 100 respondents were analyzed as follows, 33 respondents from shabab,33 respondents from Ponda Mali and 34 respondents from Milimani. This means that the questionnaire response rate was 100%

4.3 Demographic Details of respondents

4.3.1 Distribution by Gender

It was a gender based sample size where both male and female were sampled. These findings are presented in Table 4.2 showing the frequency and percentages for gender characteristics in the entire study population of 100 respondents.

Table 4.2 Participation in the survey by Gender

Gender	Frequency	Percentage
Male	45	45
Female	55	55
Total	**100**	**100**

Male respondents were more than female respondents.

4.3.2 Distribution by Age

An examination of the respondents by age distribution was carried out. Those results are presented in table 4.3 below

Table 4.3 Age Distribution among the respondents

Age group	Frequency	Percentage
Below 25 years	18	18
26-30 years	21	21
31-40 years	35	35
Above 40 years	26	26
Total	**100**	**100**

The results revealed that majority of the respondents were aged above 30 years. Very few household heads were aged below 25 years of age.

4.3.3 Distribution by Education

The survey established the education level among the respondents. These results are presented in Table 4.4 below

Table 4.4 Education levels among respondents

Educational Level	Frequency	Percentage
Secondary	15	15
College	45	45
Degree	25	25
Master Degree	5	5
Total	**100**	**100**

Most of the respondents have gone beyond secondary school level.

4.3.4 Distribution by Income

The survey established the levels of income among the respondents.These results are presented in table 4.4 below

Table 4.5 Income levels among respondents

Income level	Ponda Mali		Shabab		Milimani		Total % for each level
	F	%	F	%	F	%	
Less than 5000 Kshs	2	6.2	3	9.2	0	0	7
10,000-20,000 Kshs	18	54.5	4	12.2	1	3.0	23
20,000-50,000 Kshs	13	39.3	20	60.2	13	38.2	46
50,000-100,000 Kshs	0	0	4	12.2	11	32.3	15
Above 100,000 Kshs	0	0	2	6.2	9	26.5	11
Frequency	**33**		**33**		**34**		**100**
Total (%)	**100**		**100**		**100**		**100**

It was noted that majority of the respondents earned between Kshs 20,000-50,000 per month. Thus they can be considered middle income earners. Most of the respondents from Ponda Mali earned Below Kshs. 20,000, most of the respondents in Shabab earned above Kshs.20, 000 while most of the residents of Milimani earned above kshs.50, 000. From these results, we can conclude that Ponda Mali was a low income area; Shabab was a middle income area while Milimani was a high income area.

4.3.5 Awareness of flourosis.

The study sought to find out the levels of awareness on flourosis among residents of Nakuru town. These findings are presented in table 4.5 below

Table 4.6 Levels of awareness on fluorosis in Nakuru Town

	Frequency	**Percentage**
Aware	72	72
Unaware	28	28
Total	**100**	**100**

Majority of the residents (75%) across the Town were aware of what flourosis was while 25% of them were totally unaware. They however, mainly knew about dental flourosis and did not know that the disease affects the skeletal system as well.

4.3.6 Where residents learnt about flourosis

The study sought to find out how the residents learnt about flourosis. These findings are presented in table 4.6 below

Table 4.7 where residents of Nakuru learnt about flourosis

	Frequency	**Percentage**
From CDN	3	3
From other sources	97	97
Total	**100**	**100**

Very few, (3%) of the residents had learnt about flourosis from the CDN program. Majority of them (97%) learnt about it from other sources. This means that the CDN does not have much direct contribution to knowledge on flourosis among the residents

4.3.7 Factors that contribute to flourosis

The respondents gave various reasons as to what they thought contribute to flourosis. These included water, volcanic soil and high levels of fluoride in water while some did not know. This shows that the residents were adequately knowledgeable on the causes of flourosis. The findings are presented in table 4.4 below.

Table 4.8 Factors residents thought contribute to flourosis.

Cause of flourosis	Ponda Mali		Shabab		Milimani		Total % for each estate
	F	%	F	%	F	%	
Water	16	48.4	18	54.5	19	55.8	43
Volcanic soil	2	6.1	2	6.1	5	14.7	9
Borehole water	2	6.1	3	9.1	4	11.7	9
Levels of flouride	2	6.1	3	9.1	3	8.8	8
Unaware	11	33.3	7	21.2	3	8.8	21
Frequency	**33**		**33**		**34**		**100**
Total	**100**		**100**		**100**		**100**

From these findings, we can see that most of the people who were unaware of factors that contribute to flourosis came from the low income area. People from the middle and high income areas were more knowledgeable on the signs and causes of flourosis

4.3.8 Signs of flourosis

The study established what residents thought were the signs of flourosis. These results are presented in the table 4.6 below.

Table 4.9 What the residents thought are the signs of flourosis

Signs	**Frequency**	**Percentage**
Brown teeth	59	59
Decay teeth	3	3
Broken teeth	1	1
Yellow teeth	3	3
Bad oduor	6	6
Weak bones	3	3
Unware	25	25
Total	**100**	**100**

Most of the respondents were well versed with the common signs of flourosis which they named. These included, brown teeth, decayed teeth, broken teeth, yellow teeth, bad odour and weak bones. Very few were totally unaware.

4.3.9 Awareness on the CDN water quality program

The study sought to establish if the residents knew about the CDN program. These results are presented in table 4.9 below

Table 4.10 Awareness about the CDN water quality program

	Frequency	**Percentage**
Aware	25	25
Unaware	75	75
Total	**100**	**100**

Majority of the residents (75%) did not even know of the existence of the project. Only 25% of the respondents had ever heard about CDN. This shows that the CDN has not been able to penetrate the market effectively to offer the residents its products and services and also educate the residents on flourosis.

4.3.10 Awareness on how the CDN program operates

The study established level of awareness on the CDN program. These results are presented in the table below.

Table 4.11 How CDN operates according to residents

Awareness	**Frequency**	**Percentage**
Unaware	81	81
Flouride removal buckets	16	16
Supply water	3	3
Total	**100**	**100**

Most of the residents were unaware on how the CDN project operates. The few who were aware thought they work by providing fluoride filters and free water.

4.3.11 Use of CDN fluoride filters

The study established how many residents use filters from CDN. These results are presented in the table below

Table 4.12 Use flouride filters from CDN by residents

Use of CDN filters	**Frequency**	**Percentage**
Used	19	19
Never used	81	81
Total	**100**	**100**

Most of the residents had never used a fluoride filter from CDN and did not know anybody who did. This points to the fact that most people are not taking measures to filter the fluoride out of their drinking water or they may be using other means apart from CDN filters.

4.3.12 Measures taken to prevent flourosis

Most of the residents took some steps to try and prevent flourosis in their households. The measures taken included boiling water, using water guard to treat water, buying bottled water, brushing with tooth paste and using CDN filters. These findings are presented in the table below

Table 4.13 Measures taken by residents to prevent flourosis

Measures	**Ponda Mali**		**Shabab**		**Milimani**		**Total (%)**
	F	**%**	**F**	**%**	**F**	**%**	
Boiled water	8	24.2	9	27.2	2	5.8	19
Using waterguard	4	12.2	7	21.2	5	14.7	16
Buying bottled water	0	0.0	1	3.1	14	41.2	15
Toothpaste	10	30.3	8	24.3	3	8.8	21
Using CDN filters	3	9.1	4	12.1	2	5.8	9
No measure taken	8	24.2	4	12.1	8	23.5	20
Frequency	**33**		**33**		**34**		**100**
Total	**100**		**100**		**100**		**100**

These results show that most of the residents had misconceptions about flourosis for instance they thought that boiling water and brushing teeth may prevent flourosis. This is untrue.

4.3.13 Rating residents' knowledge of flourosis

Using a likert scale, the residents were asked to rate their knowledge on flourosis from 0-10 with 0 being very poor and 10 being very good

These results are presented in the table below

Table 4.14 How residents rate their knowledge on flourosis

Rate	Frequency	Percentage
0	25	25
1	3	3
2	9	9
3	9	9
4	6	6
5	12	12
6	12	12
7	12	12
8	3	3
9	3	3
10	6	3
Total	**100**	**100**

Most of the residents rated their knowledge of flourosis very poorly with majority of them rating themselves below average. This is inconsistent because according to the researcher their knowledge of flourosis was acceptable for a non-expert in the field. As we have seen in earlier results, many of the residents were well aware of what flourosis is, its causes, signs and preventive measures.

4.3.14 Rating of CDN performance by residents

Using a likert scale, the residents were asked to rate the performance of the CDN program from 0-10 with 0 being very poor and 10 being very good.

These results are presented in the table below

Table 4.15 How residents rated performance of CDN program

Rate	Frequency	Percentage
0	56	56
2	3	3

3	9	9
4	9	9
5	9	9
6	6	6
7	3	3
8	3	3
Total	**100**	**100**

It is to be noted that majority of the respondents rated the program very poorly. This could be due to the fact that they don't even know of its existence and workings.

4.4. The findings of the experiment on the CDN bucket flouride filters

An experiment was conducted to determine the current levels of flouride in untreated water and levels of flouride in the same water after deflouridation with the filter buckets. Those findings are presented below

4.4.1 Extent of flouride removal from drinking water

The flouride filters were found to reduce flouride in drinking water as follows;

4.4.2 Total mean average before deflouridation

$$= \frac{\textbf{Total Flouride level in samples before deflouridation}}{\textbf{Total number of houses}}$$

$$= \frac{142.33}{30}$$

=4.744mg/L

This value also reflects the average levels of fluoride in drinking water before deflouridation within Nakuru town. This shows that the fluoride levels are high as compared to the recommended who standard of 1.5mg/L

4.4.3 Total mean average after deflouridation using the filters

=<u>Total Flouride levels in samples after deflouridation</u>

Total number of houses

= <u>1.449</u>

30

=0.483mg/L

This value reflects the level of flouride in drinking water after using the bone char flouride filters for deflouridation.

4.4.4 Extent of fluoride removal

Therefore the mean difference is

4.744-0.483

= 4.261mg/L

This value also reflects the extent of removal of flouride from drinking water using the bone char flouride filters. These findings prove that the fluoride bucket filters are effective deflouridators as they were able to remove an average of 4.261mg/L of fluoride from the water.

4.5.4 Comparison of fluoride levels after filtration to WHO and national standards

The levels of fluoride in the filtered water as compared to acceptable WHO standards was

1.5-0.483

= - 1.107mg/L

These findings show that the levels of fluoride after deflouridation fall within the recommended WHO standard of not more than 1.5mg/L. This proves that the fluoride filters provided by CDN are an effective way of deflouridation.

These findings are further summarized in the table below

Table 4.16 The extent of flouride removal from drinking water.

Test	**Levels of fluoride in water in mg/L**	**WHO standard on fluoride levels. (1.5mg/L)**	**National standard (1.5mg/L)**
Mean of samples for 30 houses before deflouridation Using filter from CDN(x)	**4.744**		
Mean of samples for 30 houses after deflouridation Using filter from CDN(x^1)	**0.483**		
Mean difference (x- x^1)	**4.261**		
Comparison of average levels of deflouridated water in Relation to who standard (x^1- 1.5mg/L)	**-1.107**		

From the above table, we can see that the average levels of flouride in water per household are very high when compared to the national and WHO standard of 1.5mg/L. Then after deflouridation, the levels dropped dramatically in all the households and were mostly below 1.5mg/L. It can therefore be concluded that the buckets actually reduced flouride in drinking water to a safe and acceptable level

CHAPTER FIVE

DISCUSSION OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This study sought to determine the factors influencing use of deflouridated water in Nakuru town. This was done by analyzing the knowledge and practices towards flourosis by the residents. Further, it was done by analyzing fluoride levels in water before and after filtration using bone char buckets

This chapter discusses the findings, conclusions and recommendation based on each of the objectives of the study. It also gives the contribution of the study to the general body of knowledge specifically with reference to awareness and level of flourosis in drinking water.

5.2 Summary of the findings

The main focus of this study was to analyze the effectiveness of the deflouridation process in Nakuru town. It sought to establish levels of awareness on flourosis, awareness on the CDN program and extent of flouride removal from water after deflouridation using CDN filters

In this study shows that majority of the respondents were aware of flourosis and its causes and even how to prevent it, however, majority of the residents did not take any measures to try and protect their families from getting the condition. However, their awareness on the CDN program and its mode of operation was very poor. It also emerged that very few residents of Nakuru use the fluoride filters from CDN to filter water with majority of those taking measures to purify the water using other means like boiling water and buying bottled water. The residents also rated their knowledge of flourosis very highly. This was true as most of them could identify the signs of flourosis, the causes and the different treatment options. They had limited knowledge on CDN program and also rated the performance of the CDN water quality program very poorly. This can be attributed to the fact that most of them were not even aware of its existence. The results further show that in as much as the residents know what causes the disease, they are in a dilemma as to where they could seek advice from where so that they are able to know how to treat and remove flouride in water.

The laboratory experiments for water quality were performed by the CDN Laboratory in Nakuru. The findings show that the average levels of flouride in drinking water is way above the WHO recommended value of 1.5mg/l. It was averaging 4.744mg/L which is potentially harmful to the health of residents. The average levels of flouride after deflouridation were 0.483mg/l. This means that the filters removed 4.261.mg/L of flouride from raw untreated water. This proves that the deflouridation filters supplied by CDN are an effective and safe method of deflouridation

This is summarized in the table below

Table 5.1 Summary of findings

Objective	Findings	Remark
1. To establish the extent to which the level of awareness influences use of deflouridated water.	• 72% of residents aware of flourosis, its causes and how to prevent it • 75% of residents unaware of the existence of the CDN program.	There was good awareness on flourosis but poor awareness on CDN program.
2. To determine the influence of personal characteristics on use of deflouridated water.	• 9% of residents use deflouridation filters from CDN or knows someone who does • 80% of residents take a measure to try and prevent flourosis. Some of these measures are unhelpful	People from a higher socioeconomic status use deflouridated water more.
3. To determine the extent to which method of deflouridation influences use of deflouridated water	• Current levels 4.744mg/L which is 316% Above WHO recommended levels • Levels of flouride after deflouridation was 0.483 which is 284% below WHO standard	• Flouride levels in drinking water is too high and may be harmful • Flouride filters from CDN are an effective means of deflouridation

5.3 Discussion of findings

This section will discuss the research findings and compare with the findings of other authors to see whether they concur or not.

The study sought to establish awareness on dental flourosis, it was shown that majority of the respondents were aware of flourosis and its causes and even how to prevent it, however, majority of the residents did not take any measures to try and protect their families from getting the condition. However, their awareness on the CDN program and its mode of operation was very poor. It also emerged that very few residents of Nakuru use the fluoride filters from CDN to filter water with majority of those taking measures to purify the water using other means like boiling water and buying bottled water. The residents also rated their knowledge of flourosis very highly. This was true as most of them could identify the signs of flourosis, the causes and the different treatment options.

On awareness on CDN program, it was shown that**,** they had limited knowledge on CDN program and also rated the performance of the CDN water quality program very poorly. This can be attributed to the fact that most of them were not even aware of its existence. The results further show that in as much as the residents know what causes the disease, they are in a dilemma as to where they could seek advice from where so that they are able to know how to treat and remove flouride in water. Furthermore, the findings show that many residents do not use services provided by CDN

The study also sought to establish current levels of fluoride in the waters of Nakuru town, the study shows that the current levels of fluoride in unfiltered water is high at 4.744mg/L. This finding also reflects the current levels of fluoride in drinking water before deflouridation. This is way higher than the maximum level recommended by WHO of 1.5mg/L. This means that the residents who use this water without first filtering it are at a high risk of developing dental and skeletal flourosis.

Fluoride may be an essential element for animals and humans. For humans, however, the essentiality has not been demonstrated unequivocally, and no data indicating the minimum nutritional requirement are available. To produce signs of acute fluoride intoxication, minimum oral doses of at least 1 mg of fluoride per kg of body weight were required (Janssen et al., 1988).

Many epidemiological studies of possible adverse effects of the long-term ingestion of fluoride via drinking-water have been carried out. These studies clearly establish that fluoride primarily produces effects on skeletal tissues (bones and teeth). Low concentrations provide protection against dental caries, especially in children. The pre- and post-eruptive protective effects of fluoride (involving the incorporation of fluoride into the matrix of the tooth during its formation, the development of shallower tooth grooves, which are consequently less prone to decay, and surface contact with enamel) increase with concentration up to about 2 mg of fluoride per litre of drinking-water; the minimum concentration of fluoride in drinking-water required to produce it is approximately 0.5 mg/litre.

However, fluoride can also have an adverse effect on tooth enamel and may give rise to mild dental fluorosis (prevalence: 12–33%) at drinking-water concentrations between 0.9 and 1.2 mg/litre (Dean, 1942). This has been confirmed in numerous subsequent studies, including a large-scale survey carried out in China (Chen et al., 1988), which showed that, with drinking water containing 1 mg of fluoride per litre, dental fluorosis was detectable in 46% of the population examined. The extent of exposure from food was not clear in these studies. In general, dental fluorosis does not occur in temperate areas at concentrations below 1.5–2 mg of fluoride per litre of drinking-water. In warmer areas, because of the greater amounts of water consumed, dental fluorosis can occur at lower concentrations in the drinking-water (IPCS, 1984; US EPA, 1985a; Cao et al., 1992). It is possible that in areas where fluoride intake via routes other than drinking-water (e.g., air, food) is elevated, dental fluorosis will develop at concentrations in drinking-water below 1.5 mg/litre (Cao et al., 1992). Elevated fluoride intakes can also have more serious effects on skeletal tissues. Skeletal fluorosis (with adverse changes in bone structure) may be observed when drinking-water contains 3–6 mg of fluoride per litre. Crippling skeletal fluorosis usually develops only where drinking-water contains over 10 mg of fluoride per litre (IPCS, 1984). The US EPA (1985b) considers a concentration of 4 mg/litre to be protective against crippling skeletal fluorosis. The relation between exposure and response for adverse effects in bone has been considered by IPCS (2002)

Lastly, the study which sought to establish levels of fluoride in water after filtration with the CDN filters, it was shown that after filtration, the average fluoride levels in drinking water was 0.483mg/L. This is within the WHO recommended range of not more than 1.5mg/L. This effectively proves that the CDN filters actually carry out their intended purpose of reducing fluoride to acceptable levels thus the residents face a decreased risk of developing dental and skeletal flourosis as a result.

5.3.1 National standard on acceptable level of fluoride in water

There is no evidence to suggest that the guideline value of 1.5 mg/litre set in 1984 and reaffirmed in 1993 needs to be revised. Concentrations above this value carry an increasing risk of dental fluorosis, and much higher concentrations lead to skeletal fluorosis. The value is higher than that recommended for artificial fluoridation of water supplies, which is usually 0.5–1.0 mg/litre (Murray, 1986).

In setting national standards or local guidelines for fluoride or in evaluating the possible health consequences of exposure to fluoride, it is essential to consider the intake of water by the population of interest and the intake of fluoride from other sources (e.g., from food and air). Where the intakes are likely to approach, or be greater than, 6 mg/day, it would be appropriate to consider setting a standard or local guideline at a concentration lower than 1.5 mg/litre. A range of treatment technologies are available; however, in some areas with high natural fluoride levels in drinking-water, the guideline value may be difficult to achieve, in some circumstances, with the treatment technology available. However in this case, the study has proven that the CDN flouride filters are an effective and reliable way of deflouriating water

5.4 Conclusions

It can therefore be concluded that the CDN water quality program has been partially able to achieve its objectives.

The program has not been able to create awareness on flourosis in Nakuru town as most of the residents who were knowledgeable on flourosis had not learnt about it from CDN but from other sources

The program has also not been able to increase awareness on their existence and their products and services

The only objective the program has fully achieved is that It has been able to supply an affordable fluoride filtration technology that provides residents with clean and safe drinking water

5.5 Recommendations

1. The CDN program should increase efforts to create awareness on flourosis among the residents. This can be achieved by organization of seminars, partnering with local institutions like schools and churches to have seminars on flourosis and also use of electronic and print media
2. The CDN program should increase efforts to create awareness on the program itself, its products and services among the residents. This can also be achieved by organization of seminars, partnering with local institutions like schools and churches to have seminars on the program and also use of electronic and print media to advertise themselves.
3. The program can extend its area of operation to include other areas that are flouride endemic in Kenya.

5.6 Areas for further research

Subject to the findings of this research, further studies can be carried out on the same subject. Further research could be carried out to determine why the CDN has not been able to effectively penetrate its target population. The research could also be expanded to include other regions in Kenya that also lie within the fluoride belt for example Baringo and Koibatek where CDN also operates

Additional focus should be placed on incorporating a wide range of variables to produce a more significant study which could be generalized to a larger population.

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APPENDICES

APPENDIX 1: LETTER TO RESPONDENTS

Maurine Akinyi Ochieng

P.o Box 63092-00200, Nairobi

Tel: 0721753304

Email: maureen_ochieng@yahoo.com

To,

The Project Manager, CDN Water Quality Program,

P.o Box 938- 20100, Nakuru

Dear Sir,

RE: CARRYING OUT AN EVALUATION RESEARCH PROJECT OF YOUR FACILITY

I am a University of Nairobi student undertaking a Masters of Arts in Project Planning and Management. I am also a dentist by profession. I would like to evaluate your program as my thesis towards partial fulfillment of the requirements of my degree. I will mainly focus on evaluating if the program has achieved its main objective of reducing the fluoride levels in water using the bone char method. This will involve measuring fluoride levels in water before and after use of deflouridating agents provided by your program. It will also evaluate if the program has been able to create awareness on Flourosis among Nakuru residents The results of the study will benefit your program as you will be able to get an independent evaluation on the performance of your program. The results of the evaluation will only be used for academic purposes. Thank you in advance.

Yours faithfully,

Maurine A. Ochieng

APPENDIX 4: QUESTIONNAIRE TO RESPONDENTS

My name is Maurine Ochieng. I am a University of Nairobi student undertaking a Masters Degree in Project Planning and Management. I am also a Dentist by profession. I would like to evaluate the CDN Water Quality Project as my thesis towards partial fulfillment of the requirements of my degree.

I will mainly focus on evaluating if the program has achieved its main objective of reducing the fluoride levels in water using the bone char method and also creating awareness among residents of Nakuru Municipality.

I would hereby like to request you to fill in the attached questionnaire to help in my study. Any information you give will be treated with absolute confidentiality and will be used for academic purposes only

Section A: Background information

1. What is your Gender? Please tick

[ ] Female [ ] Male

2. What is the age of the household head? ____________________

[ ] Below 25 years [ ] 26-30 years

[ ] 31-40 years [ ] Above 40 years

3. Highest level of Education

[ ] Secondary [ ] College

[ ] Degree [ ] Masters Degree

4. Residence ………………………

5. Occupation: ………………………

6. Monthly income in KSh --------------------------

Below Ksh.5,000 Between Ksh.5,000-20,000

Between Ksh.20,000-50,000 Between Ksh.50,000-100,000

Above Ksh.100,000

SECTION B:

1. Do you know what Flourosis is?

a) Yes b) No

2. Where did you learn about flourosis from?

a) CDN b) Other sources

3. What are the major causes of flourosis in your area?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………….

4. Name the signs of flourosis that you know.

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………….

5. Are you aware of the CDN Water Quality Program?

a) Yes b) No

6. How does CDN water quality program work?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………….

7. Do you know anyone who uses the fluoride removal buckets supplied by CDN?

a) Yes   b) No

8. Do you take any measures to ensure you and your family are not affected by flourosis? If yes, briefly explain

…………………………………………………………………………………………………
…………………………………………………………………………………………………
………………………………………………………………………

9. On a scale of 1-10, how would you rate your knowledge on flourosis?

(With 0 being very poor and 10 very good)

……………………………………………………………………………………….

10. On a scale of 1-10, how would you rate the performance of the CDN program?

(With 0 being very poor and 10 very good)

………………………………………………………………………………………

APPENDIX 5: FLOURIDE TEST DATA

	Fluoride levels in water samples in mg/L Before defluoridation					Mean per House	National standard	Mean for all houses	Fluoride levels in water samples in mg/L After defluoridation					Mean per house	Mean for all houses
	1	**2**	**3**	**4**	**5**			**4.744**	**1**	**2**	**3**	**4**	**5**		**0.483**
Hse 1	3.0	3.0	3.1	3.2	3.1	**3.08**	**1.5**		0.4	0.5	0.5	0.5	0.5	0.48	
Hse 2	7.4	7.3	7.28	7.4	7.4	**7.356**	**1.5**		0.17	0.16	0.17	0.18	0.17	0.17	
Hse 3	3.0	3.1	3.0	3.0	3.0	**3.02**	**1.5**		0.02	0.01	0.02	0.02	0.01	0.016	
Hse 4	3.0	3.1	3.0	3.1	3.0	**3.04**	**1.5**		0.06	0.06	0.05	0.05	0.06	0.056	
Hse 5	3.0	3.1	3.0	3.1	3.0	**3.04**	**1.5**		0.22	0.2	0.21	0.22	0.21	0.212	
Hse 6	3.0	3.0	3.1	3.0	3.1	**3.04**	**1.5**		0.1	0.1	0.15	0.17	0.13	0.13	
Hse 7	5.3	5.2	5.3	5.4	5.3	**5.3**	**1.5**		1.4	1.4	1.5	1.3	1.4	1.4	
Hse 8	4.6	4.5	4.4	4.3	4.6	**4.48**	**1.5**		0.2	0.2	0.25	0.27	0.3	0.244	
Hse 9	5.7	5.6	5.7	5.6	5.7	**5.66**	**1.5**		0.7	0.67	0.69	0.71	0.7	0.694	
Hse 10	6.2	6.1	6.3	6.2	6.1	**6.18**	**1.5**		0.02	0.02	0.03	0.02	0.02	0.022	
Hse 11	7.0	7.0	7.2	7.1	7.1	**7.08**	**1.5**		0.17	0.16	0.18	0.17	0.16	0.168	
Hse 12	4.1	4.2	4.1	4.0	4.1	**4.1**	**1.5**		0.2	0.25	0.2	0.27	0.29	0.242	
Hse 13	3.8	3.7	3.8	3.7	3.8	**3.76**	**1.5**		0.25	0.2	0.27	0.29	0.2	0.242	
Hse 14	3.7	3.6	3.5	3.7	3.8	**3.66**	**1.5**		1.2	1.31	1.4	1.17	1.9	1.396	
Hse 15	3.1	3.2	3.3	3.1	3.1	**3.16**	**1.5**		0.06	0.05	0.05	0.06	0.06	0.056	

Hse 16	5	5.1	5	5.1	5	**5.04**	**1.5**		0.2	0.2	0.25	0.22	0.21	0.216	
Hse 17	5.2	5.1	5.3	5.2	5.2	**5.2**	**1.5**		1.4	1.4	1.5	1.3	1.4	1.4	
Hse 18	4.7	4.6	4.8	4.7	4.7	**4.7**	**1.5**		0.2	0.2	0.25	0.26	0.29	0.24	
Hse 19	5.6	5.5	5.4	5.7	5.6	**5.56**	**1.5**		1.5	1.48	1.6	1.5	1.65	1.546	
Hse 20	6.5	6.5	6.6	6.4	6.7	**6.54**	**1.5**		0.17	0.18	0.16	0.16	0.17	0.168	
Hse 21	6.9	6.9	7.0	6.8	6.5	**6.82**	**1.5**		0.17	0.16	0.16	0.18	0.17	0.168	
Hse 22	3.9	3.5	3.9	3.8	3.7	**3.76**	**1.5**		0.4	0.4	0.5	0.4	0.4	0.42	
Hse 23	3.7	3.5	3.6	3.4	3.3	**3.5**	**1.5**		0.1	0.15	0.17	0.09	0.08	0.118	
Hse 24	4.5	4.3	4.5	4.7	4.0	**4.4**	**1.5**		0.7	0.75	0.8	0.69	0.72	0.732	
Hse 25	3.1	3.4	3.7	3.4	3.3	**3.38**	**1.5**		0.05	0.06	0.06	0.07	0.07	0.062	
Hse 26	5.1	5.4	5.3	5.5	5.1	**5.28**	**1.5**		1.4	1.45	1.39	1.4	1.39	1.406	
Hse 27	5.4	5.4	5.2	5.7	5.3	**5.4**	**1.5**		1.2	1.31	1.4	1.17	1.28	1.272	
Hse 28	4.5	4.4	4.1	4.5	4.1	**4.32**	**1.5**		0.2	0.25	0.24	0.28	0.22	0.238	
Hse 29	5.4	5.3	5.7	5.3	5.6	**5.46**	**1.5**		1.5	1.43	1.48	1.6	1.61	1.524	
Hse 30	7.3	7.2	7.1	6.9	7.0	**7.1**	**1.5**		0.19	0.2	0.17	0.24	0.28	0.216	
Control	0	0	0	0	0	**0**			0	0	0	0	0	0	

Photograph of CDN bucket filters