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Master Dissertation

A research thesis proposal submitted to Pan African University for the partial fulfillment of the requirements for the award of Master of Science in Water Policy at the Pan African University for Water and Energy Sciences (including climate change)

Presented by

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Title of Thesis:
DEFEATING FLUOROSIS IN RURAL KENYA USING THE KILIMANJARO CONCEPT: A FEASIBILITY STUDY IN NAIVASHA

Defended on 03/09/2019 Before the Following Committee:

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DEDICATION

This research proposal is dedicated to all those who have experienced first-hand, the reality and the consequences of high fluoride consumption through unsafe water, unknowingly.

They include the fluorosis victims in Nakuru, Turkana, Baringo, Narok, Kiambu Counties and the other fluorosis affected Counties in Kenya, Africa and around the World. I hope they hear their voices in the issues articulated in this research work.

STATEMENT OF THE AUTHOR

This research proposal is my original work. Other's ideas and words have been properly cited.

This work has not been presented for award of a degree in any other University.

Signed …………………………………… Date ……03/09/2019……………………

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PAUWES/2017/MWP08

BIOGRAPHICAL SKETCH

WAGATUA Ruth Wambui is a Kenyan, born in Naivasha. Before joining the Pan African University Institute of Water and Energy Sciences (including climate change) - (PAUWES), to pursue her MSc in Water Policy, She received her Bachelor's degree training in Environmental Planning and Management from Kenyatta University and a Higher diploma in Human Resource Management from the College of the Human Resources Management in Kenya. She attended Njoro Girls' high school, Nakuru County, Kenya.

Ruth previously served as the Personal Assistant to the Member of the National Assembly, Naivasha Constituency, worked as a Technical staff in Geosurvey Engineering and Environmental Services Company LTD, Nairobi, Kenya where they dealt with surveying, mapping, urban planning and environmental consultancy projects. She trained as an environment officer during her Bachelor's field practicum period in the sub county of Naivasha, Environment Department. Ruth also worked as an administrative intern during university holidays at Pillar Audio Visual Services LTD, Nairobi, Kenya. While at PAUWES, she served as the Vice President, Marketing and Communications, PAUWES Entrepreneurship and Innovation Club, Tlemcen, Algeria.

Researching on fluorosis has given her an opportunity to put a face to what hydrofluorosis is, and what can be done as easily implementable preventive and remediation measures, from a victim's perspective because it's an issue she has interacted with personally and intimately.

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ABBREVIATIONS AND ACRONYMS

BATs	Best Available Technologies
CDN WQ	Catholic Diocese of Nakuru Water Quality
CGN	County Government of Nakuru
CIDP	County Integrated Development Plan
DE	Diatomaceous Earth
EARV	East African Rift Valley
F^-	Fluoride
FAC	Fluorosis Affected Communities
ICT	Information and Communications Technology
JMP	Joint Monitoring Programme
KC	Kilimanjaro Concept
KENGEN	Kenya Electricity Generating Company Limited
NACOSTI	National Commission for Science and Technology
NAIVAWASS	Naivasha Water Sewerage and Sanitation Company
NTISUDP	Naivasha Town Integrated Strategic Urban Development plan
NWMP	National Water Master Plan
NWSS	National Water Services Strategy
ODA	Official Development Assistance
RWH	Rainwater Harvesting
SDGs	Sustainable Development Goals
TCCAF	The Coca-Cola Africa Foundation
UNICEF	United Nations International Children's Emergency Fund.
VEI	Vitens Evides International
WASH	Water, Sanitation and Hygiene
WASREB	Water Services Regulatory Board
WHO	World Health Organization
WRA	Water Resources Authority
WSTF	Water Services Trust Fund
WSUP	Water and Sanitation for the Urban Poor

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ABSTRACT

The water in Lake Naivasha and the rainfall in the sub-county is enough to provide the whole population in the area with fluoride-free drinking and cooking water. Lake and rainwater can be blended with natural fluoride-contaminated waters in appropriate ratios to obtain safe and adequate water. The primary element of the study is to provide possible simple and sustainable non treatment options easily implementable in the rural areas that will enable management of the fluoride – water chemistry in a frugal manner in order to make universal safe drinking water provision in Naivasha a possibility especially since seemingly, groundwater will never cease to serve as a drinking and cooking water source. The research used a mixed research design applying both quantitative and qualitative methods where the data was collected via questionnaires and through observation. Each objective was analyzed using appropriate statistical tests. Experimental data was analyzed using both simple descriptive statistics, MS Excel and the Statistical Package for Social Sciences IBM version 21 for analysis. The total, mean, minimum and maximum values were used to assess the spread of the data. Frequencies, percentages and mean difference were used for analysis. After the data analysis, data was presented in the form of tables and figures with descriptive analysis explaining what was deduced. Interpretation of results was done in comparison to past findings and discussed, compared with existing literature on similar or related works. To cover for and nourish fluorosis affected communities, the findings reveal and suggest that, there's a need to design a unique model that ensures pollution and water abstraction costs cast on the principles in place, towards Lake Naivasha, and collected in the form of revenues, as well as the water sector trust fund and Hell'sGate National Park proceeds are ring-fenced to ensure the local community benefits from it by construction of safe water solutions and water treatment plants that serve the catchment community. There's need for formulation of corporate accountability policies that will ensure the multimillion horticultural industry, conference tourism, fishing, and geothermal exploitation in Naivasha reflect on the thriving capacity of the local population in terms of safe water provision. Community social enterprises need to be empowered to take action towards ending Fluorosis in Naivasha and to be utilized as channels through which implementation of initiatives aimed at educating the people on water safety, capacity building and ensuring improved fluorosis eradication wisdom among the locals is made a reality. Households need to be trained on how to come up with home policies that ensure water safety.

Keywords: hydro fluorosis; Lake Naivasha; rainwater harvesting; water blending; water safety

RÉSUMÉ

L'eau du lac Naivasha et les précipitations dans le sous-comté suffisent à fournir à toute la population de la région une eau potable et de cuisine sans fluor. L'eau du lac et l'eau de pluie peuvent être mélangées à des eaux naturelles contaminées par le fluorure dans des proportions appropriées pour obtenir une eau saine et adéquate. L'élément principal de l'étude est de fournir des options simples et durables de non traitement facilement applicables dans les zones rurales qui permettront de gérer la chimie de l'eau fluorée de manière économe afin de rendre possible l'approvisionnement universel en eau potable à Naivasha, d'autant plus que, apparemment, les eaux souterraines ne cesseront jamais de servir de source d'eau potable et de cuisson. La recherche a utilisé un plan de recherche mixte appliquant des méthodes à la fois quantitatives et qualitatives où les données ont été collectées par le biais de questionnaires et par l'observation. Chaque objectif a été analysé à l'aide de tests statistiques appropriés. Les données expérimentales ont été analysées en utilisant à la fois des statistiques descriptives simples, MS Excel et le progiciel de statistiques pour les sciences sociales IBM version 21 pour l'analyse. Les valeurs totales, moyennes, minimales et maximales ont été utilisées pour évaluer la diffusion des données. Les fréquences, les pourcentages et la différence moyenne ont été utilisés pour l'analyse. Après l'analyse des données, les données ont été présentées sous forme de tableaux et de figures avec une analyse descriptive expliquant ce qui a été déduit. L'interprétation des résultats a été faite par rapport aux résultats antérieurs et a fait l'objet d'une discussion, comparée à la littérature existante sur des travaux similaires ou connexes. Pour couvrir et nourrir les communautés touchées par la fluorose, les résultats révèlent et suggèrent qu'il est nécessaire de concevoir un modèle unique qui garantisse que les coûts de pollution et d'extraction de l'eau, calculés selon les principes en vigueur, vers le lac Naivasha, et collectés sous forme de revenus, ainsi que les recettes du fonds fiduciaire du secteur de l'eau et du parc national de Hell'sGate, sont affectés à la construction de solutions d'eau potable et de stations de traitement de l'eau qui desservent la communauté du bassin versant, afin que la communauté locale en bénéficie. Il est nécessaire de formuler des politiques de responsabilisation des entreprises qui garantiront que l'industrie horticole multimillionnaire, le tourisme de conférence, la pêche et l'exploitation géothermique à Naivasha reflètent la capacité florissante de la population locale en termes d'approvisionnement en eau potable. Les entreprises sociales communautaires doivent être habilitées à prendre des mesures pour mettre fin à la fluorose à Naivasha et à servir de canaux pour la mise en œuvre d'initiatives visant à éduquer la population sur la sécurité de l'eau, à renforcer les capacités et à garantir une meilleure sagesse en matière d'éradication de la fluorose parmi la population locale. Les ménages doivent être formés à l'élaboration de politiques domestiques garantissant la sécurité de l'eau.

Mots clés : hydro fluorose ; lac Naivasha ; collecte des eaux de pluie ; mélange des eaux ; sécurité de l'eau

CHAPTER 1. INTRODUCTION

1.1 Background information

WHO | UNICEF JMP report (2019) reported that on a worldwide scale, billions of people are continuing to suffer from poor access to water translating to some 2.2 billion people worldwide who do not have safely managed drinking water services. Improved quality, continuity of supply and access to safe drinking water is not a usual occurrence (Kiambuthi, 2018) and remains one of the critical problems confronting rural communities (Josephine-Mary & Sam, 2011) in many parts of the world. These challenges are not just peculiar to Africa South of the Sahara (Alkurdi et al., 2019), Fluoride contamination at inappropriate concentrations in water is a major problem across the globe, with health hazards such as dental and skeletal fluorosis (Shakir et al., 2016).

WHO | UNICEF JMP progress report had a special focus on inequalities (WHO, 2017) and revealed that there's a growing injustice with access to water and sanitation driven by personal wealth and the populations most at risk of being left behind in terms of basic services provision, are the poorest and fragile living in rural remote areas.

Hydrofluorosis affects in an often dramatic way, the lives and the quality of life of many tens of millions of people, mostly in some of the poorest developing countries and therefore (Frencken, 1990), acknowledges that fluorosis is an illness demanding serious measures and compared to the fight against diseases such as malaria or Acquired Immunodeficiency Syndrome, whose eradication programmes have been extensive and expensive, fluorosis has only received modest attention and efforts (Frencken, 1990).

According to (Ndé-Tchoupé et al. 2019) there's an increasing number of scientific and technical reports predicting a strong probability of hard time ahead for the victims of high fluoride consumption in the African population and the three major arguments are: the lack of a frugal defluoridation technology, the insufficient education on water safety among the affected population and the high poverty rate. Most of domestic water requirements is met from unimproved groundwater sources, especially for those living in rural fluoritic areas (Salifu, 2017) where the water is most characterized by high levels of fluoride, sometimes as high as 10mg/L which is contrary to WHO's upper limit of fluoride concentration in drinking water of 1.5mg/L (WHO, 2017).

Water quality has an impact on the public health and is one of the main indicators of the quality of service provided to the consumer (WASREB, 2016).

There are many areas of the world that have fluoride beyond permissible levels in drinking water and they include China, India, Sri Lanka, and the Rift Valley countries in Africa. Fluorosis affected region originates in the Jordanian Valley in West Asia and extends southward through Sudan, Eritrea, Ethiopia, Kenya, Uganda, Tanzania, Malawi, and Mozambique (Kwai et al., 2016).

Kenya is not the only African country struggling with Fluorosis, in their research, (Avocefohoun et al., 2017; Baouia & Messaitfa, 2015; El-Jaoudi et al., 2012 ; Faye et al., 2007; Lukiko et al., 2016; Satake et al., 2009; Srikanth et al., 2002) observed high fluoride levels in most African countries and they include Algeria, Benin, Cameroon, Chad, Ethiopia, Eritrea, Egypt, Ghana, Lybia, Malawi, Mauritania, Morocco, Nigeria, the Republic of South Africa, Senegal, Sudan, Uganda, Kenya and Tanzania. Malago et al. (2017) observed that the countries with highest maximum fluoride levels in Africa are those falling within the Rift Valley especially the East African Rift Valley (EARV). Such countries include Kenya, Tanzania and Ethiopia with maximum fluoride levels ranging between 250 and 2,800 mg/L. In Kenya, fluoride contamination in groundwater is a serious issue (Pittman & Mohan, 2016), a study by Malago et al. (2017) reported Kenya to be the country with the highest level of maximum fluoride where 2,800 mg/L, was found in Lake Nakuru which is one of the Rift Valley Lakes in Kenya.

Most areas of Naivasha Sub County are fluorosis affected ("Naivasha," n.d.) and the groundwater mostly contain fluoride in concentrations exceeding the 1.5 mg/L permissible limit established by WHO. There is no confirmed data available on the number of people depending on groundwater with higher contents of fluoride. Data on the quality of water is not readily available either, the local population do not have the power to know and be in control of the fluoride concentrations they consume in their drinking and cooking water. The predisposing factors to hydrofluorosis has been poverty, low levels of education on what fluoride is and a lack of water safety coping strategies for the rural communities.

1.2 Problem Statement

The population in Naivasha Sub County is growing and will spur further in about five years upon the anticipated construction of the standard gauge railway (Railways Africa, n.d.), an industrial Park and a proposed dry port, as indicated in the County Government of Nakuru (CGN, 2014) County integrated development plan (CIDP 2018-2022). The proposed water networks (NTISUDP 2014-2034) run through the urban areas leaving out the rural areas. Nakuru County needs to strategically plan ahead to ensure availability of improved, adequate and good quality water supply leaving no one behind, to sustainably satisfy the population in a universal manner, before the population outgrows it's water supply.

Fluoride contamination of the groundwater in some parts of the Naivasha Sub County has exposed the population in the fluorosis affected communities to fluoride-related health hazards and this water challenge has resulted to serious socioeconomic implications like for example dental fluorosis has determined how self-esteem is shaped. The victims have been subjected to demeaning remarks that dental fluorosis is an indication of poverty and or poor oral hygiene. Getting front office jobs and being recruited in the army has been a challenge because dental fluorosis is not in the code of the army recruitment processes.

Lake Naivasha is an important inland freshwater lake in that it plays a vital role by supporting many socioeconomic activities such as a multimillion horticultural industry, conference tourism, fishing (Becht and Harper, 2002; Kundu et al., 2010; Ndungu et al., 2015) therefore being a goldmine for revenue. Oil rich countries have policies in place that ensure establishment of desalination plants ("Water Desalination in the Middle East," n.d.), Naivasha Sub County besides being a gold mine for revenue collection is geothermal rich but construction of water treatment systems to ensure utilization of Lake Naivasha for domestic use to supply water to the different wards of Naivasha Sub County has never been implemented and community water projects still pay overwhelming electricity bills. Some residents from Kamere Olkaria ward rely on water from Lake Naivasha for domestic use and consume it untreated, which as a rule is seriously contaminated, either biologically or chemically. The only feasible and readily available sources of water that the other local communities have been forced to sort after, is groundwater and rainwater. Prolonged consumption of water containing high levels of fluoride has resulted in many of the residents suffering from fluorosis which presents with browning of the tooth enamel in dental fluorosis and deformed joints and bones in skeletal fluorosis (Gevera, 2017; Pratyay Pratim Datta, 2013). These conditions are irreversible.

Even though groundwater remains the only readily available source for rural water supply in Naivasha Sub County, little is known about the factors (natural and/or anthropogenic) that control the groundwater chemistry and, hence the quality and source of fluoride contamination as well as its distribution. There is no estimation made yet of the children under the age of 10years, who live within this area and constantly consume water from unimproved groundwater sources that could be at the risk of dental and skeletal fluorosis. Among the fluorosis victims and their children, fluorosis coping strategies are close to none. The potential of rainwater as an alternative source for domestic purpose or supplement to existing water supply sources especially for rural areas has never been exploited. Maiella ward is an area with water inadequacy yet their roads are half eaten by gully erosion. The water that is perennially lost through run off needs to be harnessed and harvested for the local people. There is a small aircraft from the local flower farms that have been accused by the residents of Hellsgate ward, of air spraying targeting rain bearing clouds hence modifying the local climate. This is a threat to proposed rain reliant solutions in the study area especially Hellsgate ward. The piping system for water supply to Rapland in Olkaria Ward via KENGEN is rusty and very small in diameter compared to the piping installation for energy exploration with is colorful and adequate in diameter.

There has been fluorosis eradication programmes on track, such as water and sanitation for the urban poor (WSUP), The Coca-Cola Africa Foundation (TCCAF), Catholic Diocese of Nakuru water Quality Programme (CDN WQ), Vitens Evides International (VEI) ensuring safe and good quality water supply but they have not been delivering for the poor person in the remote areas of Naivasha. No studies have been done to assess impact of these programmes on the livelihoods of beneficiaries, particularly on how sustainably the quality of life of individual persons have been improved when it comes to defeating fluorosis. Until now the usual approach, has failed to be sufficiently effective. It is to this end that priorities need to be identified and set for improving population health in fluorosis affected communities.

1.3 Significance of the study

Having no known effective and sustainable treatment for fluorosis and other related health hazards, remediation of fluoride-contaminated groundwater sources intended for drinking is a necessity, to avoid the ingestion of excess fluoride as a preventive measure against this permanent risk which has no cure. This research proposal will raise awareness and give a roadmap for a self-reliant and sustainable initiative that will provide safe and good quality water to the children born in areas that have been put on the periphery for the longest time, rural low-income communities of Naivasha sub County at the beginning, before venturing into the other communities facing this fluorosis challenge in Kenya and Africa at large all with an overall vision of empowering a healthy tomorrow for children born and raised in rural fluorosis affected communities. The study will also provide the entrusted water resources development planners and implementers with an overview regarding fluoride in groundwater, the resulting consequences of consuming the water and the possible fluoride adaptation responses, for the sole purpose of improving the quality of life in the fluorosis affected communities of Kenya and Africa at large.

It is therefore of paramount importance to have meaningful research done, that is responsive to the people's needs, to be a useful bridge in communicating the health implications of fluoride consumed from groundwater and the possibility of remediating the water by blending it with harvested rain water as an intervention.

1.4 Scope of the work

The study focused on the rural fluorosis affected communities of Naivasha – Kiwanja Ndege, Cossovo, Rubiri, Mirera, Karagita, Mwiciringiri of Hellsgate ward; Mountain view, Kihoto, Manera of Lakeview ward; Kanjoo, Mithuri of Viwandani ward; Jikaze, Longonot of Maai Mahiu ward; Maraigushu, Kinungi of Naivasha East Ward; Maiella Ward; Lomayiana, Rapland and Kamere of Olkaria ward. The population target was 300 respondents, for the households, water experts and water vendors. Field work was done between April and July 2019.

1.5 Objectives of the study.

1.5.1 Main Objective

The main goal of this research is to provide the entrusted water resources development planners and implementers with an overview in regard to fluoride removal from groundwater through the non-treatment option for the sole purpose of improving the quality of life in the rural fluorosis affected areas of Kenya.

1.5.2 Specific Objectives

The study intends to fulfil the following specific objectives:

1. To carry out a hydrocensus assessment of drinking water sources in Naivasha sub-county;
2. To find out the water quality of the drinking water sources in Naivasha sub county;
3. To understand the human health implications associated with either drinking the groundwater with high level Fluoride or consumption of vegetables irrigated and cooked with the groundwater contaminated with Fluoride
4. To evaluate the performance of blending harvested rain water with water of high Fluoride concentration in reducing Fluoride in drinking and cooking water.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This chapter focuses on literature that discusses and reviews the presence of fluoride in groundwater sources, in Africa, then in Kenya and health implications, causes of F^- in groundwater, the guiding legal and institutional blueprints for human consumption water and technologies available to reduce F^- in the drinking water.

2.2 Presence of fluoride in groundwater sources, in Africa, then in Kenya and Health implications

Hydrofluorosis has been prevalent for as long as history can convey (Dahi, 2016). (Marwa et al, 2018) notes that fluoride at high concentration in surface and groundwater in the EARV was documented during the colonial period even before this region had a name. Ndé-Tchoupé et al., (2019a) further notes that Germans reported elevated fluoride concentrations in natural waters in the old Tanganyika days and in 1930s, and this is when clear relationship between high fluoride level and mottling of teeth was established. Since the early 1960s, many studies have been conducted to combat fluorosis in this region (Malago et al, 2017; Marwa et al, 2018 ; Ndé-Tchoupé et al, 2019a ; Ndé-Tchoupé et al, 2019; Oladoja et al, 2018; Wagutu et al, 2018).

Previous studies on fluorosis in Kenya (Williamson, 1953; Gitonga & Nair 1982; Nair & Gitonga, 1984) reported occurrence of severe forms of dental fluorosis in nearly all parts of Kenya with a prevalence of 80% in the Rift Valley. Similar studies have reported high levels of fluoride in borehole waters in many parts of Kenya (Wambu & Muthakia, 2011).

Dahi (2016) notes that there are five fluoride belts in the world and two are situated in Africa; the North African Belt covering parts of Morocco (El-Jaoudi et al., 2012), Algeria, Libya, Egypt, Eritrea (Srikanth et al., 2002), Mauritania, Benin (Avocefohoun et al., 2017), Western Sahara (Almerich-Silla et al., 2008) and the Great Rift Valley belt which is the world's most severe fluoride belt, covering parts of Lebanon, Syria, Jordan, Egypt, Sudan, Somali, Ethiopia, Kenya, Uganda and Tanzania.

Tanzania, Kenya, and Ethiopia are the three countries in Africa most affected by the occurrence of fluoride in their Rift Valley waters. (Dahi, 2016)

(Wambu, Agong, Anyango, Akuno, & Akenga, 2014) notes that elevated proportions of fluoride have been recorded in Kenya's Uyoma, Asembo and Nyang'oma Divisions' groundwater sources.

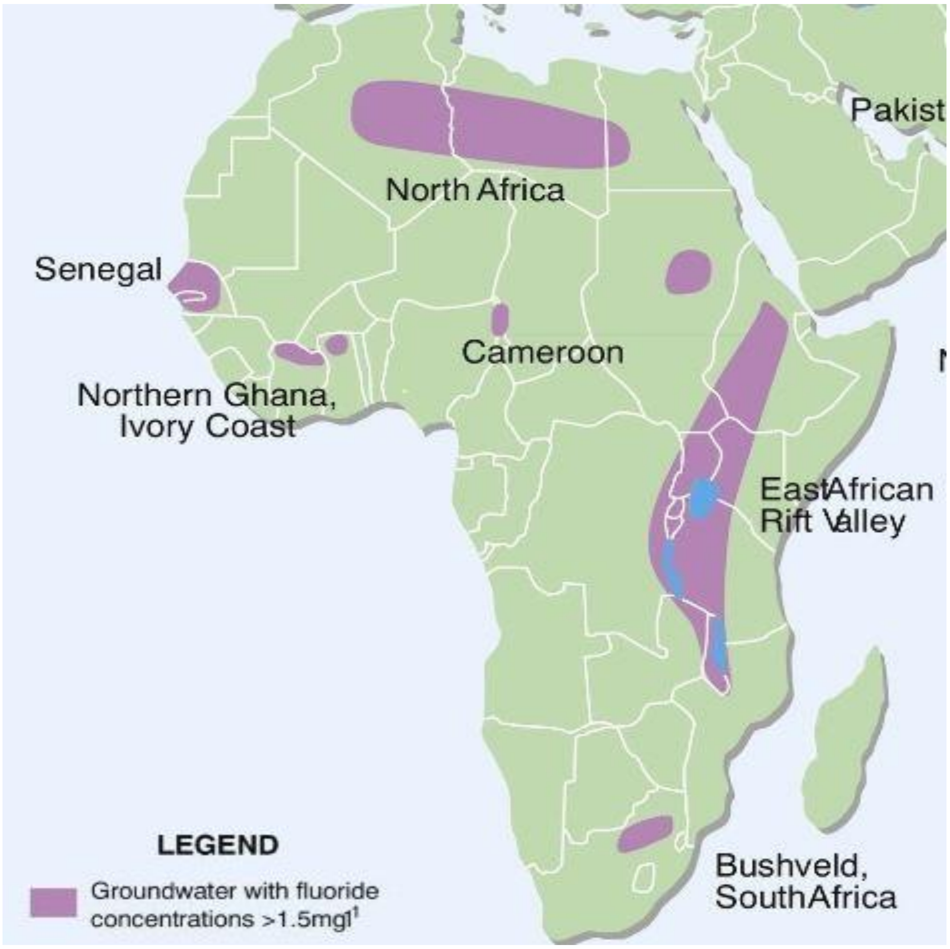

Figure 2.1. African countries with high level of fluoride in groundwater (Source: Alkurdi et al, 2019).

Historically, policy for public health has emphasized on mortality, with death rates expressing severity of disease but hydrofluorosis which is a very poorly understood fluoride induced condition represent a major burden of ill health and life decay (Fewtrell, Smith, Kay, & Bartram, 2006).

F^- is an essential element for both human and animals while it is also one of the WHO classified contaminants in ground water (He et al., 2016). Izuagie et al. (2015) reported that groundwater is usually free from waterborne diseases associated with surface water and therefore the reason it is considered to be the most preferred drinking water for most rural communities in countries such as India, Tanzania, Kenya and South Africa.

Izuagie et al. (2015) further explains that groundwater may be free of pathogens but the level of fluoride it contains is worthy of note as too low or too high concentration of fluoride in drinking water is detrimental to health. Fluoride's presence in drinking water is beneficial to the production and maintenance of healthy bones and teeth (Mourabet et al., 2012), however the ingestion and absorption of high concentrations of fluoride ions, its distribution to the tissues and bio-accumulation in bones and teeth results in many well-recognized adverse effects (Alkurdi et al. 2019), such as dental and skeletal fluorosis (Sarkar & Shekhar, 2016).

Fluorosed teeth occurs as a results of a coating effect where fluoride ions accumulate and diffuse into the enamel converting the hydroxylapatite to fluorapatite (Nair K. R et al, 1984).

Izuagie et al. (2015) further observed that absence or too low F^- concentration (<0.5 mg/L) in drinking water could lead to dental caries in children where newly developed enamel wears away as a result of acid produced from action of bacteria on sugar. The presence of fluorapatite at a critical pH of 4.5 makes the tooth structure more resistant to dental caries attacks ("Fluorapatite," n.d.)("How does fluoride protect my teeth and make them strong?," n.d.).

Wong and Stenstrom (2017) reports that Fluoride in drinking water at concentrations of 1-1.5 mg/L can strengthen the enamel, improving dental health and result in good bone development. At concentrations above 1.5 to 4 mg/L and 4-10 mg/L, dental and skeletal fluorosis is likely to occur respectively.

Besides being a cosmetic problem, dental fluorosis is a serious condition with detrimental effects in that it is socially isolating, it keeps its victims insecure and keeps them from thriving, it affects the aesthetic, emotional and even psychological aspects of an individual's life (Mohanta, 2018).

The study of Salifu (2017) notes that the toxic effects of fluoride on human health when consumed in excess amounts (beyond 1.5 mg/L), for long periods, have been known for centuries and they include: changes of deoxyribonucleic acid (DNA) structure, neurological problems such as lowering of Intelligence Quotient of children (Zhang, Lou, & Guan, 2015 ; Bashash et al., 2017), interference with kidney functioning and even death when doses reach very high levels (about 150 - 250 mg/L).

(Bashash et al., 2017; Valdez Jiménez et al., 2017) evaluated the association of in utero exposure to fluoride on the offspring and the determination of the fluoride exposure was through urine analysis during pregnancy. Their data suggests that cognitive alterations in children born from exposed mothers to Fluoride could start in early prenatal stages of life.

Mental fluorosis causes neurodegeneration triggering diseases such as Alzheimer's and other neurodegenerative and vascular diseases ("2019 Research Updates: Fluoride and Neurodegeneration," n.d.).

Other health effects related to consuming high fluoride concentrations are effects on the immune and human reproductive systems, and gastrointestinal tract health (Harrison, 2005). (Jackson et al., 2002; Alkurdi et al., 2019) also reported that fluoride can form strong bonds with other toxic metals such as aluminum and lead, altering the toxicity of the substance when digested.

2.3 Causes of F^- in groundwater

Occurrence of fluoride in African waters could be both geogenic such as the presence of fluorine-bearing minerals in rocks and sediments such as fluorspar, apatite, mica, sellaite, phlogopite, mica, rock phosphate, topaz, cryolite, (Elango and Jagadeshan, 2018).

(Padhi and Muralidharan, 2012) in their work added that there are important factors that increase F^- leaching into groundwater and they include conditions in the soil such as alkalinity, high levels of aluminum and low concentrations of calcium and magnesium oxides.

Anthropogenically, F^- is released in the environment via two main sources. Firstly, through some processes such as coal combustion where fluoride of a geological origin is released and mobilized into the environment, and secondly from the inappropriate discharge of waste products by various industries, causing fluoride to be present in water resources. The industrial waste products include nickel, steel, copper and aluminum smelting; and the industrial manufacture of masonry, ceramics, semiconductors, phosphate fertilizers and glass (Cai et al., 2017; Rasool et al., 2017; Tovar-Gómez et al., 2013; Waghmare et al., 2015).

A study by Frencken (1990) observed that areas with active volcanism, for example along the EARV have high fluoride which is also sometimes found in terrains with young marine sediments like in Senegal. (Alkurdi et al., 2019) also noted that the concentration of fluoride in groundwater resources depends on the geographical location and is largely associated with the presence of nearby volcanic activities and fumarolic gases. The local and climatic conditions necessitate adaptation of Flouride concentration in excess of 1.5 mg/l (WASREB, 2016).

2.4 Drinking water and the guiding Legal and Institutional blueprints

2.4.1 UN Agenda 2030 and World Health Organization (WHO)

WHO report is not clear on the global prevalence rate of fluorosis however it's been estimated that over a range of years, elevated fluoride concentrations in consumption water have caused tens of millions of chronic fluoride induced conditions("WHO | Inadequate or excess fluoride," 2018).

Leaving no one behind, is one of the central promises of Agenda 2030 for sustainable development (WHO, 2017). The 2018 SDGs report particularly on goal number 6, states that 3 in 10 people lack access to safely managed drinking water services (WHO, 2019). 2018 SDGs report further indicates that many people still lack access to safely managed water supplies and sanitation facilities and this hinders social and economic development. In order to reach SDG6, everyone's needs must be addressed, leaving no one behind (WHO, 2019).

Access to basic services is not only a fundamental human right, but also a stepping stone to sustainable development. Provision of safely managed water correlates with economic growth, social inclusion, poverty reduction and equality. Every citizen has the right to safe drinking water. (WHO, 2019).

The human right to safe and improved water supply was explicitly recognized in the 2010 UN General assembly as it can contribute greatly to poverty reduction and is fundamental to increasing a country's economy as well as improving a country's average life expectancy (WHO, 2018).

Safe and good quality water is critical to the health of every child under the age of 5 years and every community, therefore, it is essential to building stronger, healthier, and more equitable societies. As these services are improved in the most disadvantaged communities and for the most disadvantaged children today, they get a fairer chance at a better tomorrow (WHO, 2017).

2.4.2 Agenda 2063 and Africa water Vision 2025

Agenda 2063 | African Union, (2015) aspires for a water secure Africa and an African people with high standard of living, improved quality of life, sound health and well-being.

The water vision for Africa admits that access to basic water supply and sanitation services is highly inadequate in Africa. Statistics from the 2025 Water Vision for Africa brings to our attention that in rural Africa, about 65 percent of the population do not have access to adequate water supply and 73 percent are without access to adequate sanitation. The vision also indicates that progress in coverage has stagnated, and more people are without adequate services today, than in 1981 – 1990 Water and Sanitation Decade.

2.4.3 Convention on the Rights of a Child, United Nations General Assembly and UNICEF

The physical environment where children are born, live and play shapes many aspects of their health, safety and well-being (UNICEF, 2018).

All children have the right to clean water and basic sanitation, as stated in the Convention on the Rights of a Child, therefore, no child should be put on the periphery (CRC, United Nations General Assembly, 1989).

2.4.4 The constitution of Kenya, 2010

(The constitution of Kenya**,** 2010) chapter four on the bill of rights puts responsibility on the state promising to put in place affirmative action programmes designed to ensure that minorities and marginalized groups have a reasonable access to water.

2.4.5 Kenya Water Act No. 43 of 2016

The Act aims to shape the water sector to be in line with the Kenyan Constitution's vision of devolution. The act acknowledges that water connected functions require joint efforts, by the national government and for the county governments to adapt and implement them. The act emphasizes and places more importance to use of abstracted water for domestic functions over irrigation and alternative uses.

2.4.6 Water Services Trust Fund (WSTF)

The Water Services Trust Fund of Kenya is mandated to finance water and sanitation services for the poor and underserved communities in rural and urban areas and according to the Water Act of 2016, this state corporation is mandated to provide conditional and unconditional grants to the Counties and to assist in financing the development of and management of water services in the marginalized and underserved areas including: development of water services in rural areas considered not to be commercially viable for provision of water services by licensees (WSTF Brief, 2018).

2.4.7 National water master plan (NWMP) 2030

The NWMP counsels that in areas where hydrofluorosis is prevalent (more than 0.3 mg/L F^-), the groundwater should be utilized for other domestic uses other than drinking (JICA, 2013).

2.4.8 The National Water Services Strategy (NWSS) 2017 - 2015

The Ministry of Water and Irrigation (MWI) set out The National Water Services Strategy (NWSS) 2017 – 2015 which admits that the government is planning to elaborate a pro poor water services strategy aimed at the progressive realization of Human Rights and water. The water service providers have also been mandated to ensure socially responsible commercialization (NWSS, 2015).

2.5 Proposed budgetary allocation for the environment, natural resource, water and sanitation sector

Figure 2.2 shows the summary of proposed CGN budget by sector for the period 2018 – 2022. The budget for environment, natural resource, water and sanitation sector is only 3% of the overall allocation.

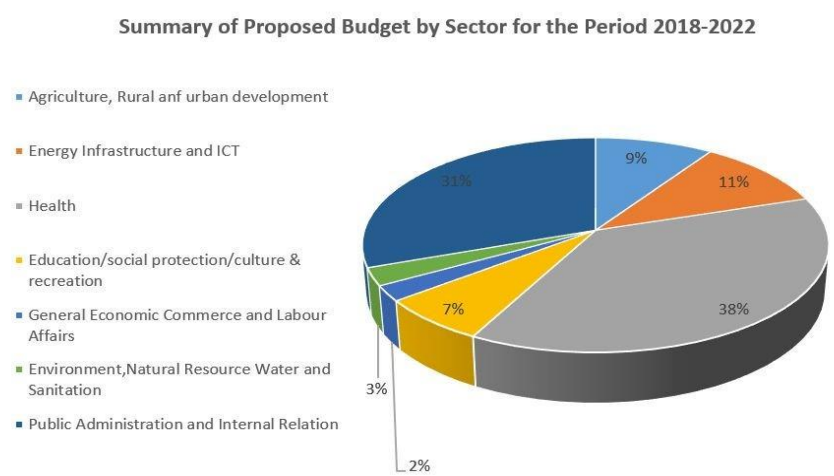

Figure 2.2: Proposed budgetary allocation for the environment, natural resource, water and sanitation sector (Source: 2nd Nakuru CIDP 2018 – 2022).

2.6 Technologies available to reduce F^- in the drinking water

Several defluoridation technologies have been developed in many places around the world, some of which are described as “Best Available Technologies” (BATs). The current methods, however, mostly have some limitations which generally make their use unsustainable and/or unacceptable under most conditions, particularly in remote areas in developing countries. This include for instance: (i) the Nalgonda technique (Karunanithi, Agarwal, & Qanungo, 2018) which is popular in some Asian countries but is known to have limited efficiency (up to about 70 %), requires careful dosing of chemicals and close monitoring to ensure effective fluoride removal, hence demanding labour, skills and time that are usually problematic under rural conditions in developing countries; (ii) the contact precipitation process, which is still under study, and moreover the reaction mechanism for the defluoridation process is thought only to be feasible with use of bone charcoal as a catalyst.

Bone charcoal (Salifu, 2017) is however not culturally acceptable in some societies due to local taboos and beliefs; (iii) adsorption using activated alumina (Salifu, 2017) as adsorbent media, which is known to be expensive especially for developing countries, (iv) adsorption with bone charcoal as adsorbent media, which is not acceptable in many places as earlier mentioned, and, (v) reverse osmosis (RO) (Karunanithi, Agarwal, & Qanungo, 2018) which has high capital and operational cost, require specialized equipment, skilled labour and a continuous supply of energy, can be implemented in Naivasha Sub county because the area is geothermal energy rich.

Filtration systems based on bone char have been more or less successfully used as effective mitigation technology for some two decades. CDN WQ is a producer and supplier of household and community bone char filters (CDN, Mueller & Jacobsen, 2007; Korir et al., 2009). Naivasha Water Sewerage and Sanitation Company (NAIVAWASS) has implemented the bone char filters. The search for an appropriate technology for the removal of excess fluoride from contaminated-groundwater still remains very critical. Among the available fluoride removal techniques, the adsorption process is generally considered as one of the most appropriate, particularly for small community water source defluoridation. This is due to its many advantages including flexibility and simplicity of design, relative ease of operation, and cost- effectiveness as well as its applicability and efficiency for contaminant removal even at low concentrations. The appropriateness of the adsorption technology, however, largely depends on availability of a suitable adsorbent. Several adsorbent materials have been developed and tested, mostly in the laboratory, for the treatment of fluoride-contaminated water including: manganese-oxide coated alumina, bone charcoal, fired clay chips, fly ash, calcite, sodium exchanged montmorillonite-Na+, ceramic adsorbent, laterite, unmodified pumice, bauxite, zeolites, fluorspar, iron-oxide coated sand, calcite, activated quartz and activated carbon (Salifu, 2017). While some of these adsorbent materials have shown certain degrees of fluoride adsorption capacity, the applicability of most is limited either due to: lack of socio-cultural acceptance, non-regenerable nature, and therefore may not be cost-effective, high cost and/or effectiveness only under extreme pH conditions. This may require pH adjustment and consequently additional capital, operation and maintenance cost, and could limit feasibility of such a fluoride removal technology in remote rural areas of developing countries. Some of the studied defluoridation materials are also available in the form of fine particles or powders, with the potential of clogging and/or low hydraulic conductivities when applied in fixed bed adsorption systems.

The laboratory synthesis of Trimetal Mg/Ce/Mn oxide-modified diatomaceous earth (DE) carried out by Gitari et al. (2017) showed the fluoride removal performance of the sorbent to be greater than 91% for solutions with initial pH range of 4 –11. Gitari et al. (2017) also evaluated and observed that carbonate ions presence would reduce the amount of fluoride removed from solution under their operational conditions. K_2SO_4 solution was found to be most suitable for regeneration of the spent Mg/Ce/Mn oxide-modified DE compared to the capacities of Na_2CO_3 and NaOH.

The possibility of regenerating the synthesized materials when exhausted proves it's economic and practical viability. However, the reusability of the spent sorbent is challenged, when it comes to groundwater with much higher fluoride content. Safe disposal of the spent adsorbent into the environment (when it can no longer be used) and a field screening of the capability of the synthesized adsorbent to treat natural fluoride-contaminated groundwater is yet to be articulated.

The lack of frugal defluoridation technologies set rolling an analysis of the affordable possibilities and in their study, (Ndé-Tchoupé et al., 2019) revealed that water blending would eliminate the need for technical defluoridation. By harvesting and storing rainwater which is the source of fluoride-free water, the scarcity problem can be resolved. By increasing the storage capacity, harvested water can be used to increase agricultural and economic productivity and enhance the well-being of the population of the EARV (Ndé-Tchoupé et al, 2019).

Water blending is a known approach to comply with recommended standards for safe drinking water and is regarded as a non-treatment option based on the mass balance of the pollutant of concern as explained in (Howe et al. 2012; Marwa et al. 2018). The required condition for water blending in the case of fluoride is to have water with high fluoride (>1.5 mg/L) as well as water with lower fluoride concentration (<1.5 mg/L). The appropriate mixing ratios required to achieve blended water with a fluoride concentration of less than 1.5 mg/L depends on the volume of rainwater needed to blend any polluted water, which increases with the initial fluoride concentration (Howe et al. 2012; Marwa et al. 2018).

2.7 Critique of the literature

From the historic to the contemporary perspectives of hydrofluorosis, no study have given information on the proportion of the population in a particular study area utilizing groundwater with high fluoride for drinking and cooking purposes.

(Dahi, 2016) focuses on the fluoride belts hence might have failed to put into consideration areas outside the belts. Impact of high water fluoride outside these fluoride belts regions remain unclear (Wambu et al., 2014).

The fluoride/IQ studies of (Zhang et al., 2015; Bashash et al., 2017; Valdez Jiménez et al., 2017) have used relatively simple designs and have failed to adequately control for all of the factors that can impact a child's intelligence (e.g., parental education, socioeconomic status and other toxic metals exposure). The studies need to explain further how fluoride reduces IQ, at what dose, at what time, and how this dose and time varies based on an individual's nutritional status, health status, and exposure to other contaminants like aluminum, lead and arsenic.

The unclear WHO's reporting on the global prevalence rate of Fluorosis indicates how poorly understood chronic fluoride induced conditions are. The fact that these conditions are none communicable, and not life threatening, has made it not a priority for the medical and the public health communities.
WHO (2019) does not classify fluorosis to be among the preventable health risks that are as a result of absent, inadequate, or inappropriately managed water and sanitation services.

Despite high fluoride levels being observed in most African countries and the Great Rift Valley belt having been termed as the world's most severe fluoride belt (Dahi, 2016; Lukiko et al., 2016), the Africa water vision for 2025 does not mention fluorosis to be among the natural threats on the sustainability of the African water resources.

The proposed CGN environment, natural resource, water and sanitation sector budget for the period 2018 – 2022 indicate that CGN still has the space to increase the budget so as to reduce too much dependence on ODA that is being reflected on the CIPD plan and the WSTF basket, because if the funders were to withdraw their support, there would be a crisis in the water sector financing.

The guiding legal and institutional blueprints on drinking water have been adequately put in writing but the gap is very clear in their implementation. They need to be further simplified and brought down to the rural communities. More is needed to be done to further the actions that need to be taken to make the blueprints' goals practical and a reality in people's lives.

Despite local production and implementation efforts to improve the quality of drinking water supplied, biochar based filtration systems have not yet enabled universal safe drinking water provision in Naivasha Sub County. The situation for each individual has not improved at all either.

The current water laws have been defined without putting into consideration all the elements that are being affected therefore downplaying the fluorosis situation and they need to be reviewed to make additional amendments on fluorosis eradication and ground water governance, especially in respect to child centered pro poor policies that will take into account the voice of a child from fluorosis affected communities because they deserve to be protected.

Fluoride situation has special needs that needs to be taken account of therefore there's a need for a unique model to be designed to cover fluorosis affected communities.

The Kenyan national and county water laws need to be more inclusive, cohesive, leaving no one behind making sure every element is covered, integrated and addressed in a more particular manner by bringing in and ensuring all the other facets that are missing are reflected.

2.8 Concluding remarks

The studies reviewed dwell on technical groundwater defluoridation techniques which are quite unaffordable in terms of their efficiency, cost effectiveness, environmental friendliness and ease of use in local communities either in household or public system. Only a few studies have suggested possible fluoride non treatment options easily implementable in the rural areas that will enable management of the fluoride – water chemistry in a frugal manner with the goal of making universal safe drinking water provision in fluorosis affected communities a possibility. There is a lack of professional help in terms of drinking and cooking water safety in the rural areas and comprehensive research into the socioeconomic consequences of endemic fluorosis seems fully justified. This study therefore serves to fill the knowledge gap in this research area in order to draw definite conclusions and to be able to tailor prevention and remediation strategies accordingly.

CHAPTER 3. MATERIALS AND METHODS

3.1 Introduction

This chapter discusses the materials and methods used in collecting and analyzing the data for this research. It encompasses the characteristics of the study area in terms of location, Physiographic characteristics of the study area**,** population, sampling methods, data collection methods, analysis procedures, ethical considerations, and limitations.

3.2 Description of Study Area

3.2.1 Location

Naivasha constituency, GPS coordinates 0°43'7.70" N 36°25'25.62" E (Geographic coordinates of Naivasha Kenya, n.d.), is located in the eastern parts of Nakuru County of Kenya (Figure 3.1). This Sub-County has eight wards: Biashara, Hellsgate, Lakeview, Maai Mahiu, Maeilla, Olkaria, Naivasha East and Viwandani and occupies a total area of 1, 685.4 km^2 (County Government of Nakuru, n.d.). Naivasha borders Kiambu County to the East, Kajiado County to the South, Narok County to the West, Nyandarua County to the North and Gilgil Sub County to the North West. (NTISUDP 2014-2034) It is situated 91km Northwest of Nairobi and 80km west of Nakuru town along the Nairobi - Nakuru Highway (A104).

3.2.2 Physiographic characteristics of the study area

Naivasha sub county experiences more rainfall in the winter than in the summer (Naivasha climate - Climate-Data.org, n.d.). The months April through September have a high chance of precipitation and dry periods are normally in January and February (Climate and average monthly weather in Naivasha, Kenya, n.d.) The wettest month is April.

The sub county has a government mandated water service provider, NAIVAWASS, and this local water utility gets its raw water from the 6 company production sites with a total of 13 boreholes (Naivasha Water and Sewerage Company | Water Provision, n.d.). NAIVAWASS serve mostly the urban population in Naivasha. The rest are served by community based organizations through community borehole projects.

Other water sources in the study area include individually harvested rainwater, individually drilled wells and a network of water shops that sell treated water to mostly those who are renting in urban poor areas.

Donkey, bicycle and motorcycle water vendors locally supply the water after buying it from the borehole projects owners where in turn, they cart, bicycle and motorcycle the water to re-sell it to consumers at most of the time unaffordable fee(Guardian Sustainable Business | The Guardian, n.d.).

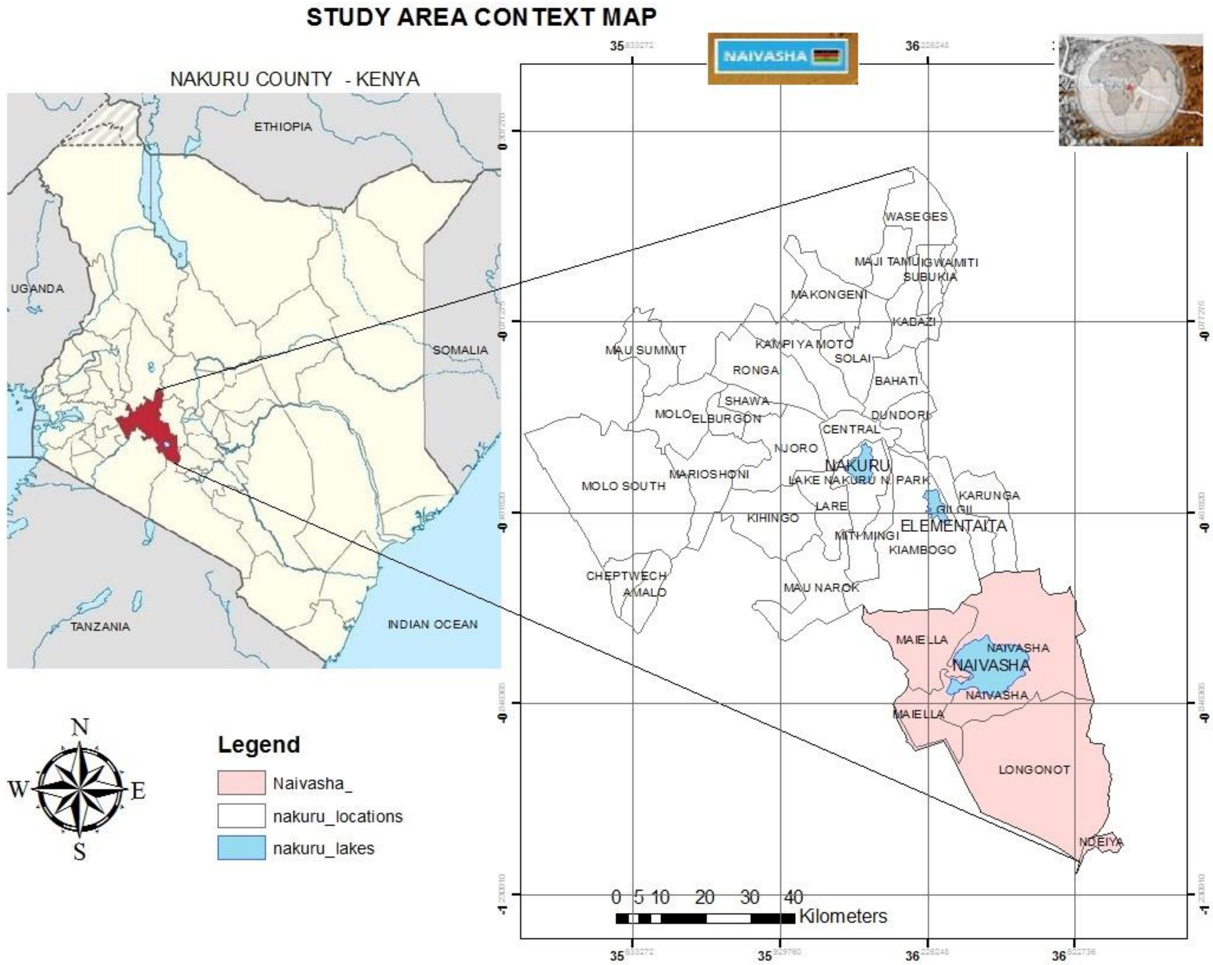

Figure 3.1: Context Map showing the study site.

3.2.3 Population

The current figures from Kenya National Bureau of Statistics estimated that a population of about 355,383 people reside in Naivasha Sub-county depicting Naivasha to be the sub county with the highest population in Nakuru County, as summarized in table 3.1 below;

National/ County	Sex			Total
	Male	Female	Intersex	
Nakuru	**1,077,272**	**1,084,835**	**95**	**2,162,202**
Gilgil	92,955	92,247	7	185,209
Kuresoi North	87,472	87,599	3	175,074
Kuresoi South	78,204	77,117	3	155,324
Molo	78,129	78,598	5	156,732
Naivasha	179,222	176,132	29	355,383
Nakuru East	92,956	100,960	10	193,926
Nakuru North	106,155	111,880	15	218,050
Nakuru West	101,797	96,854	10	198,661
Njoro	118,361	120,408	4	238,773
Rongai	99,976	99,922	8	199,906
Subukia	42,045	43,118	1	85,164

Table 3.1: Naivasha Sub-county population (Source: Census, 2019).

3.3 Data Collection Methods

Data was collected from Kiwanja Ndege, Cossovo, Rubiri, Mirera, Karagita, Mwiciringiri of Hellsgate ward; Mountain view, Kihoto, Manera of Lakeview ward; Kanjoo, Mithuri of Viwandani ward; Jikaze, Longonot Githarane of Maai Mahiu ward; Maraigushu, Kinungi of Naivasha East Ward; Maiella Ward; Lomayiana, Rapland and Kamere of Olkaria ward.

This research used a mixed research design applying both quantitative and qualitative methods. The data was collected via questionnaires and observation methods then analyzed and compared to derive an in-depth understanding of the topic of research. Questionnaires were used to collect data in household and water expert's survey.

3.3.1 Quantitative and observational data

The researcher and the research enumerators developed a data collection plan. A questionnaire containing all the questions that the enumerators would ask using SurveyCTO was developed and the form uploaded onto the SurveyCTO platform. The enumerators were able to use smart phones instead of printing large copies of questionnaire forms. They were also able to take GPS readings of the study area, took pictures and uploaded them onto the CTO server. The CTO link was shared with the supervisors and they were able to view the data collection progress and the responses that the enumerators recorded in the field. The questionnaire was used to collect data in the rural and informal areas of the wards in Naivasha. Figure 3.2 shows a geographical overview of areas where the questionnaires were administered in Naivasha Sub County.

GPS Code

N: 193 **N missing:** 0

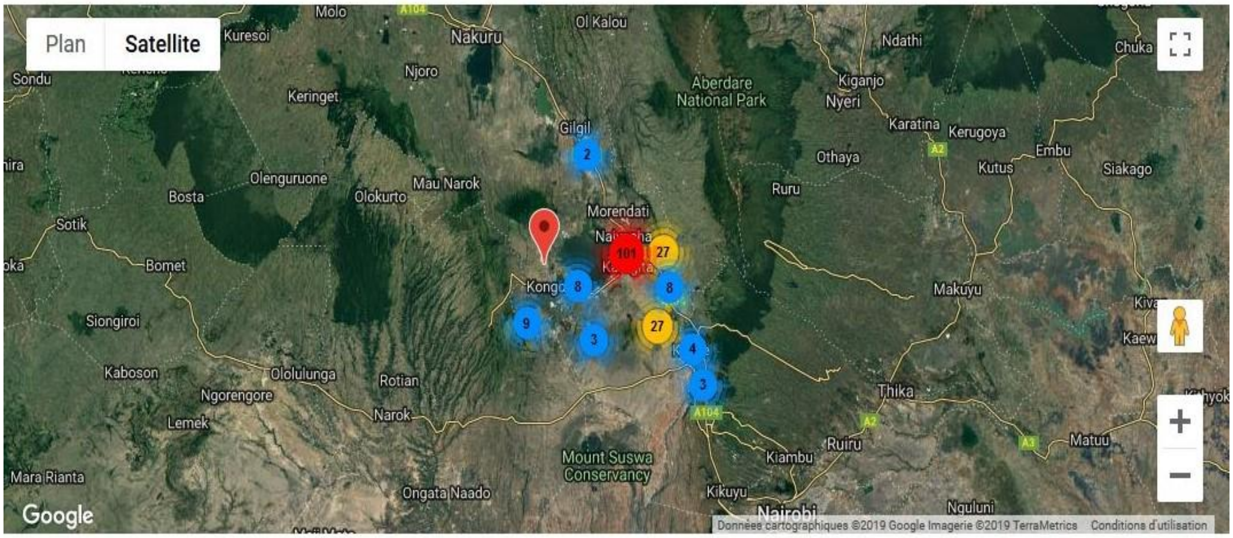

Figure 3.2: Actual areas where questionnaires were administered in Naivasha.

The researcher pretested the questionnaire with five potential respondents while observing and noting down required changes to the original questionnaire which was updated accordingly at the end of the pretesting exercise. The researcher and the three enumerators then administered the questionnaires to 193 households and 10 local water suppliers. Detailed questionnaires (Appendix 2 and 3 for households and experts) were used for a period of seventeen days. The collected data was checked for accuracy and any inaccuracies cleaned on a daily routine. Photos were taken while observable data recorded on the surveyCTO platform.

The objective on carrying out a hydrocensus assessment of drinking water sources in Naivasha sub-county was aimed at finding out the water sources serving the study area.

The researcher achieved this objective by acquisition of secondary data, through observation and using statements in the questionnaire that sought to find out the sources of water in Naivasha Sub-county.

To find out the water quality of the drinking water sources in Naivasha Sub County, the researcher officially requested for water quality data from the water resources authority in Naivasha and the meteorological department of Kenya.

To understand the human health implications associated with either drinking the groundwater with high level Fluoride or consumption of vegetables irrigated and cooked with the groundwater contaminated with Fluoride, the researcher structured the questionnaire with statements that sought the respondents' experiences on whether their drinking water is different from their cooking and irrigating water and if any of their family members was a victim of high fluoride consumption, how the fluorosis presented itself, the coping mechanisms that they have adopted and who supplies their drinking water.

To evaluate the performance of blending harvested rain water with water of high F^- concentration in reducing F^- in drinking and cooking water. The researcher used locally available oval tanks, water bottles and buckets of known capacities, rain water and naturally fluoridated water to do an experiment set up. The researcher blended rainwater with naturally fluoridated water from the local borehole, then collected 3 water samples as representatives of the 3 types of water. The researcher took the water samples to the Rift Valley Water Works Development Agency lab in Nakuru County for Fluoride analysis. To determine the level of fluoride ions in the water samples, an SPADNS reagent and photometer was used. The values from the analysis were used to determine the optimum blending ratio by calculating the amount of rainwater and the amount of high fluoride water required, to achieve blended water of reliable quality (0.5 – 1.5mg/L).

3.4 Data Analysis

Data collected were checked and edited for correctness. Each objective was then analyzed using appropriate statistical tests. Questionnaire data, water quality data and experimental data was analyzed using simple descriptive statistics, MS Excel and the Statistical Package for Social Sciences IBM version 21 for analysis. The total, mean, minimum and maximum values were used to assess the spread of the data. Frequencies, percentages and mean difference were used for analysis. After the data analysis, data was presented in the form of tables and figures with descriptive analysis explaining what was deduced. Interpretation of results was done in comparison to past findings and discussed, compared with existing literature on similar or related works. The projects objectives provided the guiding principles for the presentations and deliberations.

Word cloud analysis was generated via wordclouds.com platform where text on respondents' take when it comes to a rain water harvesting park for the whole community was analysed to determine the word frequency. The higher the frequency, the bigger the text appear.

3.5 Ethical Consideration

Ethical issues relates to the privacy of possible and actual participants, voluntary nature of participation, the right to withdraw partially or completely from the process, consent, possible deception of participants and maintenance of confidentiality of data provided by individuals or identifiable participants and their anonymity (Vanclay, Baines, & Taylor, 2013; Harris, 2017). Mugenda & Mugenda (2003) also ascertains ethical as important considerations which any research study must take care of in order to ensure high quality results and also protect the integrity of the researcher and also the respondents. Research study was inherently intrusive and the data obtained can be easily abused. The researcher was guided by a number of ethical principles, no harm was allowed to the respondents/participants as a result of their participation in the research study; the respondent's right to privacy was respected and no undue pressure was put on the respondents. Respondents was provided with sufficient initial information about the survey to be able to give their informed consent concerning participation and the use of data, permission to conduct the survey was obtained from respective authorities such as the NACOSTI and the researcher maintained confidentiality by using the data gathered exclusively for academic purposes as promised to the respondents.

3.6 Limitations

The projected 300 households and the proposed focus group discussions in the proposal could not be achieved due to financial constraints at the time of the study. The researcher had to adapt the work to the available resources. Rainfall would slow the enumerators down when it poured. The rural areas were vast in terms of accessibility and distance and some areas had low or non-existent mobile network which limited the filling of questionnaires via surveyCTO server. Acquiring secondary data from the government mandated local water supply service provider was impossible because of skepticism about the true intent of the research study. Getting dental and skeletal fluorosis clinical records was also not possible as there is no readily available documentation and it seems this conditions are not a priority to the medical and public health communities in Naivasha sub County.

CHAPTER 4. RESULTS AND DISCUSSION

This chapter presents a description of analysis of data, presentation and interpretation. The study was on defeating fluorosis in rural Kenya using the Kilimanjaro concept specifically within Naivasha Sub-county of Nakuru County in Kenya. The work is organized based on the research questions raised for the study. Data is then presented in form of frequency tables, pie-charts and bar-graphs. This presentation is based on the questionnaires administered and observations made.

4.1 General Information

This part discusses the general information relating to response rate, respondents age, gender of the respondents, level of the education, education pertaining fluoride level and water safety, treatment of drinking water, availability of shops selling water treatment products or treated water and water utilization.

4.1.1 Response rate

Completion rate is the proportion of the sample that participated as intended in all the research procedures. This study was about defeating fluorosis in rural Kenya using the Kilimanjaro concept within Naivasha region part of Nakuru County in Kenya. Therefore it was concerned with the population within the Naivasha Sub-county. The research study targeted a sample population of three hundred members while only one hundred and ninety three respondents from the sample population responded to the research questionnaires administered. The response rate is tabulated in Table 4.1 below.

Return rate	**Frequency**	**Percentage (%)**
Returned	193	64.3
Not Returned	107	35.7
Total	**300**	**100**

Table 4.1: Questionnaire return rate.

The 64.3% response rate was considered good for this study because Kothari (2005) recommends a 60% rate as sufficient and Mugenda and Mugenda (2003) recommends a return rate of 50% as adequate for analysis and reporting.

4.1.2 The education levels of the respondents

The respondents were requested to provide information about their highest education level attained. This was because the study was concerned with the means of defeating fluorosis in water within the study area. This means some formal education would be necessary among the respondents. The results are tabulated in the figure 4.1 below.

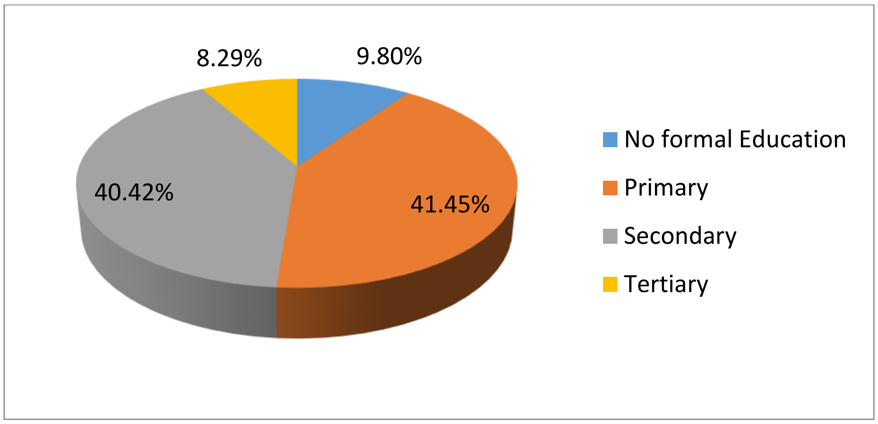

Figure 4.1: Showing the education levels of the respondents.

The respondents who had secondary level education were 40.42% and those with primary level education were 41.45%. However those with no formal education were 9.84%. It was realized that the respondents with tertiary education formed a small proportion of the respondents who constituted 8.29 % of the sample population (Mutalova & Newby, 2002). The statistics on education levels shows symptoms of mental fluorosis.

4.1.3 Distribution of the respondents by age

The study sought to establish the distribution of the respondents by age. This was because the study intended to determine the age of the respondents who participated in the research study. The results are as presented in Figure 4.2 below.

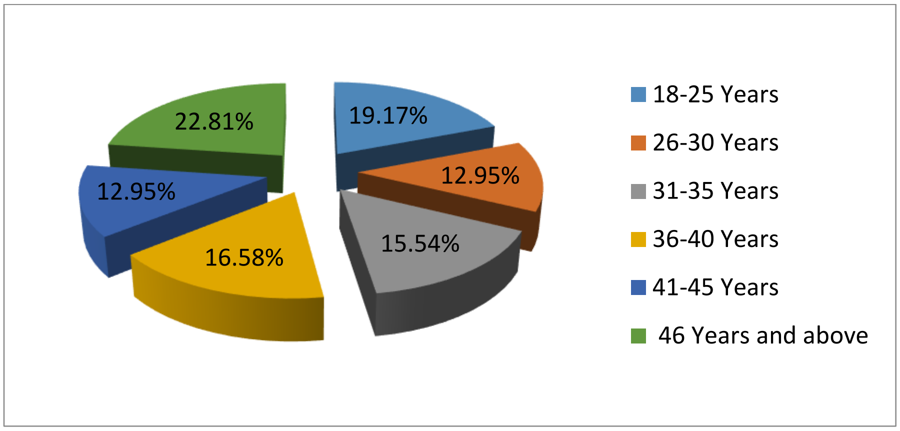

Figure 4.2: Distribution of the respondents by age.

The results shows that the respondents aged between 18-25 years represented 19.17% of all respondents. Those aged 26-30 years were 12.95 % and those between the ages of 31-35 years were 15.54 %. However, those between 36-40 and 41-45 were 16.58% and 12.95 % respectively while the respondents with 46 years and above represented 22.81 % (Mutalova & Newby, 2002).

4.1.4 Gender Distribution of the Respondents

The study sought to determine the distribution of the respondents by gender. This was to find out if gender sensitivity was a concern in the sample population. The data obtained is summarized in the Figure 4.3 below.

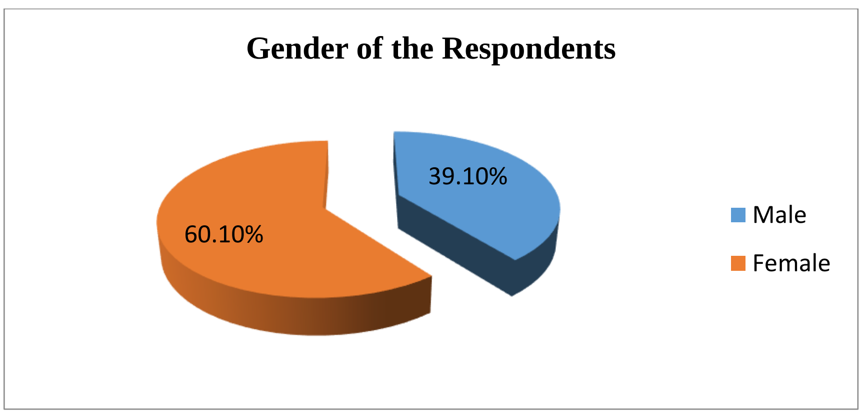

Figure 4.3: Gender Distribution of the Respondents.

Male respondents were 76 (39.1%) and the females were 117(60.1%). The percentage of females who participated in the research study was significantly higher than that of males in this study. This shows the research sample population was mainly dominated by female respondents. This was understandable because the research was conducted mainly during daytime within the households in Naivasha Sub-county where majority of male respondents were away from their households in their daily activities to earn their livelihood leaving women behind in their households to take care of the children, thus, women participated more in the research than male respondents. The bigger number and visibility of women also indicate that women being the primary caregivers, nurturers and carriers of pregnancies, it's important for them to understand the consequences of exposure to fluoride on the offspring and besides that, they need to be where public policy that touches on them and theirs is being made for successful processes and projects.

4.1.5 Education about Fluoride Levels

Respondents were requested to give their feedback regarding the education pertaining the fluoride level in the water they use within the Naivasha Sub-county. This was an important parameter because it aimed at knowing if the respondents were aware about the consequences and measures to cope up with adverse levels of fluoride in water which could lead to fluorosis. The information obtained is tabulated in Figure 4.4 below.

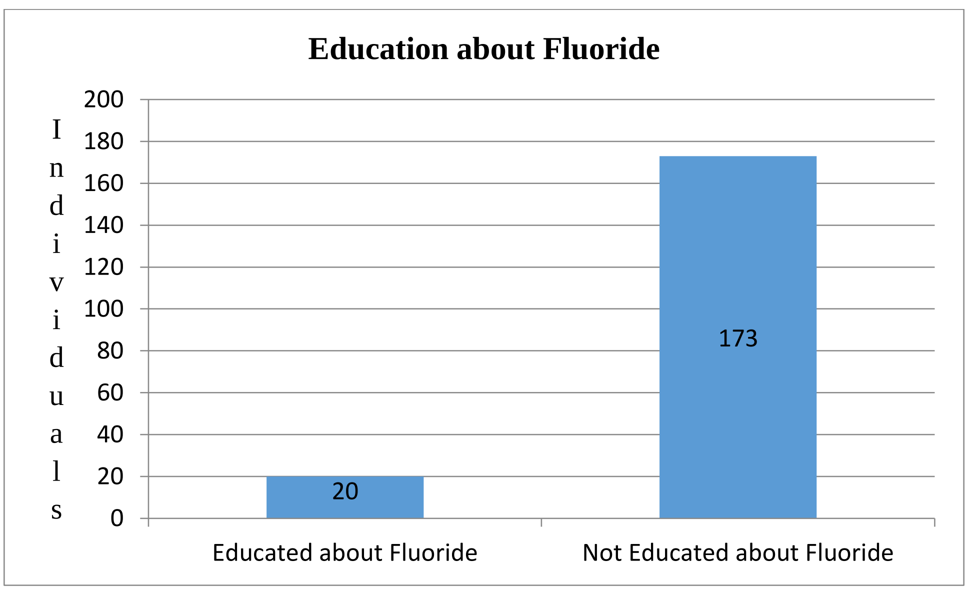

Figure 4.4: Education about Fluoride.

The research findings revealed that the majority of the respondents have not been educated about fluoride and how to cope with it before, representing 89.6 % (173) of the respondents while only 10.4% (20) of the respondents indicated that they have been educated about fluoride and how to cope with it before. This is an important consideration in order to investigate the awareness of the people living in Naivasha Sub-county if they had any information regarding the fluoride levels in water, its consequences and how to cope up with the extreme levels of the fluoride level in water before consumption in order to mitigate the negative health impacts resulting from fluorosis.

4.1.6 Treatment of Drinking Water

The research study targeted the seven local suppliers within the Naivasha Sub-County to investigate if they treated the water meant for the public use before supplying it. The research revealed that majority 57.14% of the local supplier never treated water, none of the water supplier treated water irregularly while the 42.86% of the local water supplier regularly treated water before supplying to the local population. Among the majority of the water suppliers who never treated water, 38.1% indicated the reason behind this was due to the unavailability of treating system within the area while 19.04% affirmed that the cleanliness of the water from the sources was the reason as to why they never treated water before supplying to the local population. This information has been tabulated in table 4.2 below.

Question	Regularly	Not regularly	Never
Do you currently treat your water before supplying to the local population?	**42.86%**	**0%**	**57.14%**

Table 4.2: Treatment of water by local suppliers.

The study sought to determine the intervals by which the targeted respondents within the Naivasha Sub County were treating the drinking water if they did so. This was to find out if they had some means to curb the extreme levels of fluoride in water to prevent fluorosis. The data obtained is summarized below.

Question	Regularly	Not regularly	Never
Do you currently treat your drinking water?	**11.92%**	**9.32%**	**78.76%**

Table 4.3: Treatment intervals of Drinking Water.

When the respondents were requested to indicate if the treated the drinking water; the research results indicated that only 9.32% of the respondents were treating water on irregular time intervals. 78.76% of the respondents never treated water for drinking while those who treated the water meant for drinking were only 11.92 %. For those respondents who treated the drinking water, the research study requested them to indicate the method they use to make water safe for drinking and the results were as tabulated in table 4.4 below.

Method of treating drinking water	**Frequency**	**Percentage (%)**
Boiling	29	14.66
Use of Water guard	4	1.55
Buying treated water	2	1.04
Chlorine once in a while	3	2.27
Drinking treated rainwater	8	4.31
None of the methods	2	1.04
None of the above methods	145	75.13
Total	**193**	**100**

Table 4.4: Method of treating drinking water.

From the data analysis, respondents who never used any of the method in treating drinking water were 1.04%, 1.55% indicated that they used water guard in the process of treating drinking water while only 1.04% indicated they bought the treated water for drinking. Majority of the respondents (75.13%) accounted that they never used any of the method under the research interest in treating water for drinking. 14.66% used boiling method, 2.27% and 4.31% of the individuals used chlorine once in a while and drink treated rain water respectively.

4.1.7 Availability of shops selling water treatment products/treated water

When asked to indicate availability of shops selling water treatment products or treated water, majority of the respondents (64.8%) indicated that the shops are not available while only 35.2% of the respondents indicated availability of such shops selling water treatment products in the areas they reside. This information has been shown in the frequency table 4.5 below.

Availability of water treatment products shops.	**Frequency**	**Percentage (%)**
Yes	68	35.2
No	125	64.8
Total	**193**	**100**

Table 4.5: Availability of water treatment products shops.

Research results in this category corresponded directly with the number of people who never treated water for drinking i.e. the availability of shops selling water treatment products or treated water was a significant factor in determining the number of people who treated water or drunk treated water. Thus, the higher number of individuals (78.76%) who never treated water (in section 4.1.6 above) are the majority of the respondents (64.8%) who indicated that there was unavailability of shops selling treated water or water treatment product in the areas they reside.

4.1.8 Water utilization

The respondents were further requested to indicate their responses concerning the water uses. They were asked if the drinking water was different from water used for cooking and water used for irrigation. Their responses have been shown in the Figure 4.5 below.

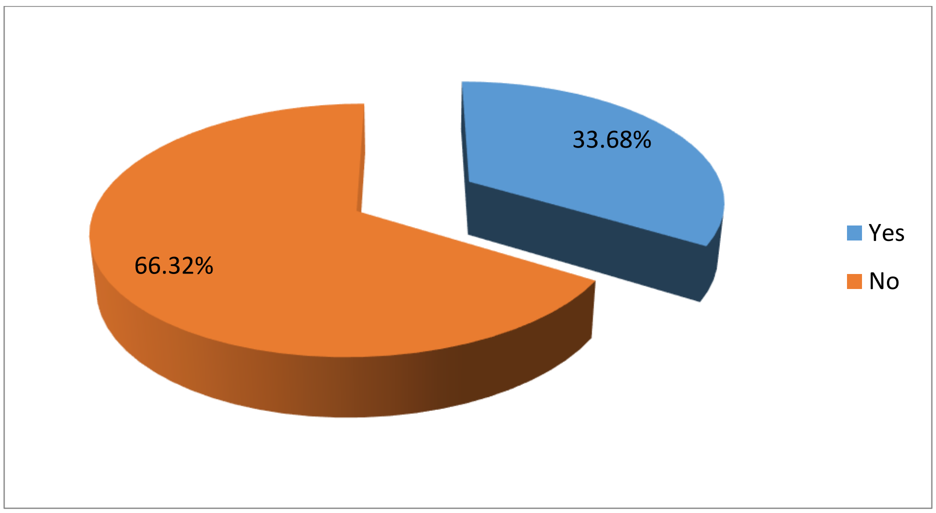

Figure 4.5: Showing water utilization.

The results show that 33.68% of the respondents agree that water used for drinking was different from that used for cooking and for irrigation while majority of the respondents (66.32%) agreed that water used for drinking was not different from that used for cooking and for irrigation.

4.2 Supply sources of drinking water in Naivasha sub-county.

The study sought to find out the sources of water from which the residents within Naivasha Sub-county obtained water for drinking as its first objective. The respondents were requested to indicate their sources of drinking water among the four sources under research interest and the information obtained is shown in table 4.6.

Sources of Water Supply	Frequency	Percentage (%)
Individually Rain harvested	48	24.87

Individually drilled well (shallow/deep boreholes)	95	48.70
Local supplier (Water Vendors)	43	22.28
Shops that sell treated water	7	4.15
Total	**193**	**100**

Table 4.6: Drinking water supply sources.

The analysis shows that 48.70% (95) majority of the respondents indicated that the drilled wells within the area of residence supplied them with water for drinking and only 4.15 % (7 respondents) indicated that they obtained water for drinking from the available shops that sell treated water. However 22.28 % (43 respondents) and 24.87 % (48) of the respondents responded that they obtain the drinking water from local supplier and from individually rain harvested sources.

The research study investigated the perception of the respondents in reference to rain water harvesting for the whole community as shown in table 4.7 below.

Responses	Frequency	Percentage (%)
It would be a helpful project to reduce water shortages.	37	19.2
Would be very helpful.	8	4.1
Project that would really help in improving water supply.	35	18.1
It would be a helpful project to increase water supply.	26	13.5
Good project.	9	4.7
It would be a helpful project to help the community.	11	5.7
Good to us locals.	13	6.7
It would make lives simpler.	2	1
It would be a good project if it employs the local youths.	19	9.8
Would not be helpful because almost all plots have water now.	9	4.7
It would be a good project to reduce the price of water in the area.	24	12.5
Total	**193**	**100**

Table 4.7: Respondents take on rain water harvesting park for the whole community.

When the respondents were asked about their take on rain harvesting park for the whole community, majority had positive perception towards it who indicated that it was a good project represented by 4.7%,12.5% responded that it will reduce the price of water in the area,9.8% indicated it will be good project if it employs the local youths,1% indicated it will simplify the life while 5.7 % indicated it would be a helpful project to help the community.However,13.5%,18.1% and 4.1 % indicated that It would be a helpful project to increase water supply, Project that would really help in improving water supply and the project would be very helpful respectively. Majority of the respondents 19.2 % (37 individuals) indicated that it would be a helpful project to reduce water shortages while only 9 respondents (4.7%) responded that it would not be helpful because almost all plots have water now. The results indicate that the respondents would value RWH Park project.

Figure 4.6: Word cloud Analysis results for Respondents take on rain water harvesting park for the whole community.

Proximity to the water source (water kiosk) was determined and only 35.24% (68) of the respondents indicated they were close to water sources while majority of the respondents 64.76% (125) were far away from the water kiosks as shown below in table 4.8 below.

Proximity to the water Kiosks	**Frequency**	**Percentage (%)**
Yes	68	35.24
No	125	64.76
Total	193	100

Table 4.8: Proximity to water kiosks.

The study sought to find out the cost per unit charge of water in which the residents within Naivasha Sub-county obtained water for use from the local suppliers and the information obtained is shown in table 4.9 below. From the findings of the study, majority of the respondents representing 23.3 % (45 respondents) indicated that they bought water for 20 shillings (approx. 0.20 USD) per 20 litres containers, 5 respondents (2.6%) indicated that they obtained water for free(water was not for sale), 38 respondents (19.7%), 45 respondents (23.3%) and 41 respondents (21.2%) responded that they bought water for 5 shillings (approx. 0.05 USD) per litre, 10 shillings (approx. 0.10 USD) per 20 litres and 20 shillings per 20 litres respectively. However,1 respondent (0.6%) bought water for 100 shillings (approx. 1 USD) per drum, 17 respondents (8.8%) bought water for 30 shillings (approx. 0.30 USD) per 20 litres can, 27 respondents (13.9%) bought water for 50 shillings (approx. 0.50 USD) per 20 litres while only 9 individuals (4.7%) bought water for 67 shillings (approx. 0.67 USD) per 20 litres container. Finally1.6% (3 respondents) and 3.6 % (7 respondents) indicated that they bought water for 70 shillings (approx. 0.70 USD) per 20 L and 75 shillings (approx. 0.75 USD) per 20 L respectively. When the similar question was asked to the local water suppliers, 14.3% (1 respondent) indicated that water cost depended with the gazetted tarriff, costed 3 shillings (approx. 0.03 USD) per litre and 70 shillings (approx. 0.70 USD) per 20 litres in each case. However, water costed 5 shillings (approx. 0.05 USD) per litre and 60 shillings (approx. 0.60 USD) per 20 litre container which represented 28.6% (2 respondents) in each case.

For household members		
Cost per unit charge (Kenya Shillings)	**Frequency**	**Percentage (%)**
Not for sale	5	2.6
5 per litre (approx. 0.05 USD)	38	19.7
10 per 20 litre (approx. 0.10 USD)	45	23.3
20 per 20 litre (approx. 0.20 USD)	41	21.2
30 per litre (approx. 0.30 USD)	17	8.8
50 per 20 litre (approx. 0.50 USD)	27	13.9
67 per 20 litre (approx. 0.67 USD)	9	4.7
70 per 20 litre (approx. 0.70 USD)	3	1.6
75 per 20 litre (approx. 0.75 USD)	7	3.6
100 per drum (approx. 1 USD)	1	0.6
Total	**193**	**100**
For Local suppliers		
Cost per unit charge(Shillings)	**Frequency**	**Percentage (%)**
It depends(Gazetted tariff)	1	**14.3**
3 per litre (approx. 0.03 USD)	1	**14.3**
5 per 20 litre (approx. 0.05 USD)	2	**28.6**
60 per 20 litre (approx. 0.60 USD)	2	**28.6**
70 per 20 litre (approx. 0.70 USD)	1	**14.3**
Total	**7**	**100**

Table 4.9: Cost per unit charge.

The targeted research respondents were also requested to indicate if there were water blackouts from the water sources they obtained water from and their responses have been shown in Figure 4.7 below;

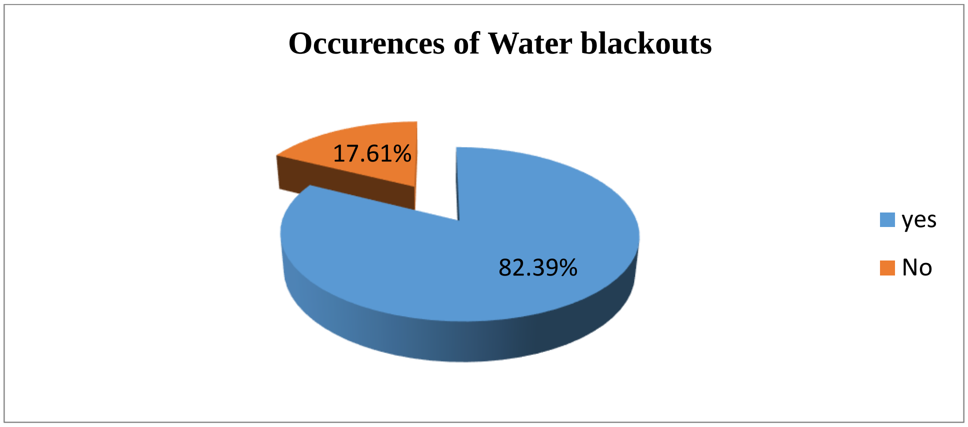

Figure 4.7: Occurrences of water blackouts (households' perspective).

From the pie figure 4.6 above, it's clear that 82.39% of the respondents agreed that the water from their local sources was not readily available due to water blackouts. However, 17.61% of the respondents indicated that there were no cases of water blackouts. When the same question about the occurrence of the water blackout was directed to the local suppliers of water, 71.4% of the water supplier indicated that there was water black out due to higher water demand in the area while the reaming water suppliers 28.6% said the water was readily available as there were no water blackouts as shown in the figure 4.8 below.

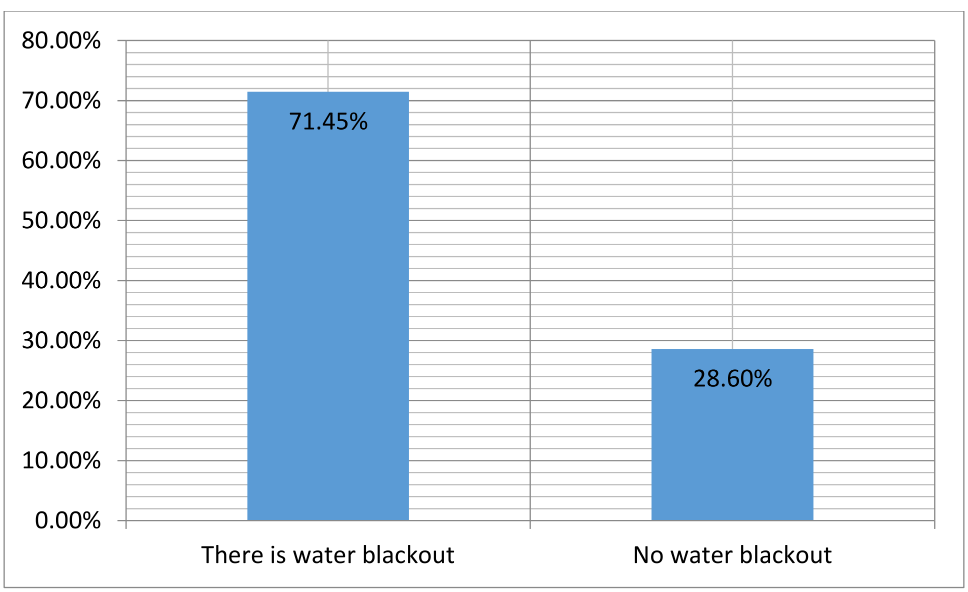

Figure 4.8: Occurrences of water blackouts (Local suppliers' perspective)

The research study examined the major reasons behind the water blackouts in the Naivasha Sub-county and the 82.9 % of the respondents indicated that dry season within the study area was the reason behind water blackout while 17.1 % attest that electricity power blackout was the cause for water blackouts within the area. This information has been simplified and indicated in the Figure 4.9 below.

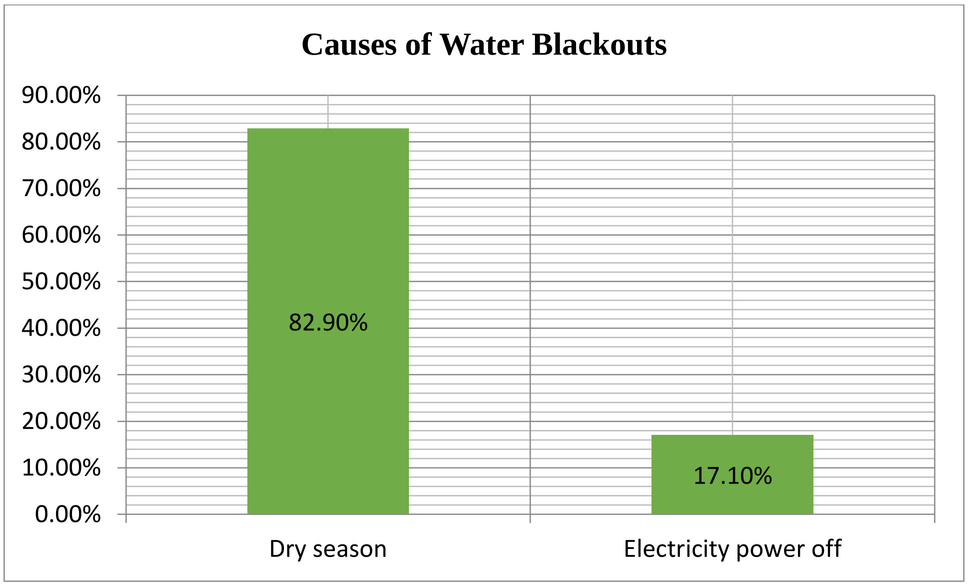

Figure 4.9: Reason for water blackouts.

The study interrogated the respondents about communication forum for sharing information between them and water supplier. Research results revealed that majority of the respondents 92.22% indicated there was no communication forum while only 7.78% indicated there was communication forum. 42.86% of the water suppliers acknowledged that there existed a communication forum of sharing information between them and their water customers while only 57.14% declined with the existence of such forum in between them and water customers. The findings obtained have been simplified in table 4.10 below.

Existence of communication Forum(By Customers)	**Frequency**	**Percentage (%)**
Yes	15	7.78
No	178	92.22
Total	**193**	**100**

Existence of communication Forum(By water suppliers)	Frequency	Percentage (%)
Yes	3	42.86
No	4	57.14
Total	**7**	**100**

Table 4.10: Existence of communication Forum.

The participants were also requested to indicate the person responsible for collecting the water for the household. The responses are recorded in table 4.11 below.

Person in charge of collecting the household water	Frequency	Percentage (%)
Men	75	39.82
Women	39	20.73
Children (girls only)	10	0.52
Children (boys only)	1	1.04
Women and children (girl)	3	2.07
Women and Children (boy)	5	2.59
Women and Children (all)	3	1.55
Men and Children	1	1.04
Entire family, anyone may go to fetch water	17	9.40
The water is piped/ connected to the household	39	21.24
Total	**193**	**100**

Table 4.11: Person in charge of collecting the household water.

From Table 4.11, 2.07%, 1.04% and 1.55% of the respondents indicated that women and girl child, men and children and women and children of both genders were responsible for collecting water for the household. However majority of the respondents (39.28%) and 20.73 % indicated that men and women were responsible for collecting water for household use. Those who indicated that girl child, boy child and women and boy child were responsible for house water collection were 0.52%, 1.4% and 2.59% respectively. However, 9.40% indicated that any individual member of the family may fetch water for the household use while water was piped to household for use only for the 21.24 % of the respondents .When ask if the available water was adequate, majority of the respondents77.72% disagree while only 22.28% agreed that water was adequate as shown below in the figure 4.10 below.

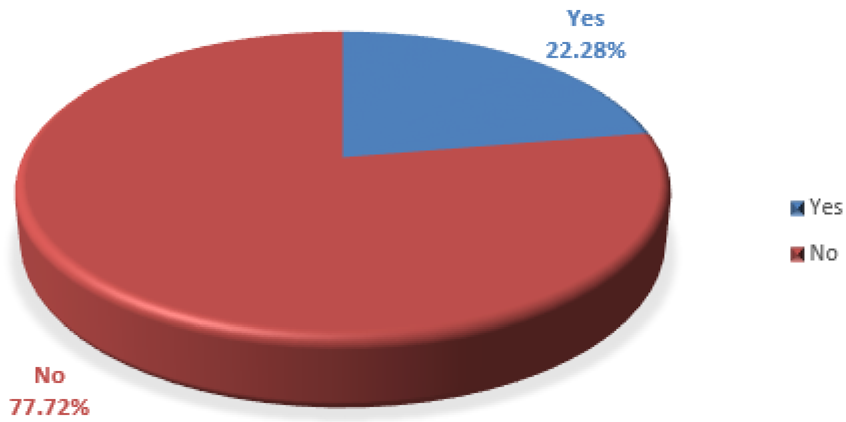

Figure 4.10: Adequacy of the available water.

4.3 The quality of the drinking water from boreholes within Naivasha Sub County.

The second objective of the study was to find the quality of drinking water among the boreholes within Naivasha Sub-county. The data on water quality for the various boreholes was acquired from the Water Resources Authority. Physical and chemical characteristics had been determined using standard methods of laboratory examinations as prescribed in Standard Methods for the Examination of Water and Wastewater. The physical parameters assessed included the Turbidity, Water rest level (WRL) and Total Dissolved Solids (TDS) while the chemical parameters included Calcium, chloride, conductivity, Fluorides, iron, Manganese, Nitrates, Nitrites, Sulphate, Temperature, alkalinity, Total dissolved solids and total hardness as shown in table 4.11 below. The water quality characteristics varied differently among the seven boreholes water points under investigation within Naivasha Sub-county. The fifty seven boreholes points included the Kabatini borehole, ST. Mary's Academy borehole, Baharini borehole, Marula borehole, Panda II borehole, Naivasha Town borehole, Ushirika borehole, Rubiri (Treated) borehole, Rubiri (Untreated) borehole, Sopa Lodge borehole, David Kangethe borehole, Mirera-Suswa W/P borehole, Erskine Enterprises Ltd borehole,Vegpro (K) Delamare Pirots borehole, Delamere NO.6 borehole, Cymmit borehole, Kreative Roses borehole, Conerstone preparatory Academy borehole, Rora Trading Company borehole, Kenya Women Holding Limited borehole, Mlimani Holding borehole, Nairobi Boarding Primary School, Naivasha Hindu Temple borehole, Marula Estate Limited borehole, Harishkumar Dhirajlal Parekh borehole, Ruaraka Ducks borehole, Delamere No 1 borehole, Delamere No 2 borehole,Valley Lilly School borehole, Longonot Farm borehole, Hyoung

Company Limited borehole, Maasai Maraa Lodge Limited borehole, Harvest Limited Borehole, Marura l Estate Limited borehole, Olij Farm borehole, Mirera Suswa borehole, Miriam Muthoni Muhiu borehole, Malewa Water project borehole, Marura Limited borehole, Mwega Water Project borehole, Maasai Mara Supa Lodge borehole, Bigot Flowers Limited borehole, Julias Kinyua Kamau borehole, Kennedy Oyunge borehole, Prakash Manoltar Heda borehole, Star Farm borehole, Heritage Resort borehole, Lizar Academy borehole, Interplant borehole, Mwago borehole, Munyu Primary School borehole,Vandeberg borehole, Rubiri Water Project borehole, Olji Breeders borehole and Kenya Agriculture Resort borehole. Analysis of the results entailed the consideration of the field values and the quality requirement for the intended beneficial use as specified by the WHO Standards of 2006. From the field investigations carried out, it was ascertained that most of the water used for domestic use comes from boreholes and thus more emphasis on boreholes was prioritized. The results of physical-chemical analysis (mean ± standard deviation, minimum, median, maximum values) are indicated in table 4.12 below. The value of these statistical parameters are first presented considering all the sampling points and then stratifying the data by the source categories. The number of borehole samples analyzed (N) were fifty seven and the applicable WHO permissible limits for drinking water are also indicated.

Parameter	Source category	N	Total	Mean	Standard deviation (±)	Min	Max	WHO
Calcium (mg/L)	Borehole	57	5,818.37	102.07	20.97	0	112	250
Chloride (mg/L)	Borehole	57	3,751.1	65.81	9.08	7	350	250
Conductivity (µS/cm)	Borehole	57	32,874.5	576.74	77.6	0.077	2,900	2500
Fluoride (mg/L)	Borehole	57	368.745	6.47	1.31	0.2	23.3	1.5
Iron (mg/L)	Borehole	57	18.701	0.32	0.05	0	1.35	0.3
Manganese (mg/L)	Borehole	57	19.132	0.34	0.47	0	3.0	0.1
Nitrate (mg/L)	Borehole	57	119.99	2.11	0.31	0	41.3	10
Nitrite (mg/L)	Borehole	57	15.23	0.26	0.52	0	4.2	10
Orthosphate (Mg/L)	Borehole	57	1.03	0.02	0.004	0	0.33	NS
Sulphate (mg/L)	Borehole	57	2,248.75	39.45	7.841	0	295	490
Temperature (°C)	Borehole	57	322.3	5.65	1.123	0	25.6	30

Phosphate (mg/L)	Borehole	57	3.25	0.06	0.12	0	0.53	0.1
Alkalinity (mg/L)	Borehole	57	19,887.3	348.9	39.53	0	1,260	500
TDS (mg/L)	Borehole	57	21,949.8	385.08	73.07	0	1,798	500
THO (°f)	Borehole	57	3,247.44	56.97	7.31	0	223	5.0
Turbidity (NTU)	Borehole	57	264.39	4.6	0.739	0	33	5.0
WRL	Borehole	57	1	0.02	0.03	0	1	NS
pH (pH Scale)	Borehole	57	419.31	7.35	1.23	0	8.8	6.5 – 8.5

Table 4.12: Total, Mean, Min and Max for parameters measured at selected sampling sites.

Key Where, **NS**- Not Specified, **TDS**-Total Dissolved Solids, **THO**-Total Hardness Observation and **WRL**-Water Rest Level.

4.3.1 Physical Quality of water

4.3.1.1Turbidity

Turbidity is the measure of the amount of particulate matter and the dissolved color suspended in water. Turbidity in water is caused by the presence of suspended matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms (Lamb, 1985). The Turbidity values were determined and they ranged from a minimum of 0 NTU and a maximum of 32 NTU. The maximum value of turbidity indicate presence of in-creased colloidal material in water whose source could be possibly contaminated from surface run-off or from suspended solids, microorganisms and vegetable material in the ground. The average mean for the turbidity among the boreholes determined was 4.6 NTU meaning that turbidity levels among the boreholes were within the WHO standard guideline. However, maximum turbidity value among the boreholes was observed in Munyu Primary School Borehole (33 NTU). The more turbid the water the more microbes present, this tends to lower the water quality.

4.3.1.2 Water rest level

Water rest level (WRL) is a measure of the mass of solids found in a volume of water and describes particulates of varied origin, including soils, metals, organic materials and debris that are suspended in water. Water rest level ranged from a minimum of 0.0 mg/L to a maximum of 1 mg/L. The mean water rest level value among the borehole water investigated was found to be

0.02 mg/L. Higher values were detected at Cornerstone Preparatory Academy borehole (0.33 mg/L).No stipulated guidelines for Orthosphate content in water by WHO.

4.3.1.3 Total Dissolved Solids (TDS)

Total Dissolved Solids, is the total amount of mobile charged ions including minerals, salts or metals dissolved in a given volume of water. TDS thus includes anything present in water other than the pure water molecules and suspended solids. TDS concentration is thus generally the sum of the cations and anions in water. Some dissolved solids come from organic sources such as leaves, silt and industrial waste and sewage. Other sources come from runoff of fertilizers and pesticides used on farms along some of the sources where sampling was done. Dissolved solids also come from inorganic materials such as rocks and air that may contain calcium bicarbonate, nitrogen, iron phosphorus, sulphur, and other minerals. From the table 4.11 above, the TDS values obtained from the tested boreholes ranged between a minimum value of 0 mg/L and a maximum value of 1,798 mg/L. The mean TDS of the sampled boreholes calculated was 385.08 mg/L with the maximum limits beyond WHO standards being observed in Julias Kinyua Kamau borehole (1,798 mg/L).Increase in level of total dissolved solids increases the electrical conductivity which is true according to the study in reference to the higher electrical conductivity of 2,900 µS/cm being detected in this borehole only.

4.3.2 Chemical Quality of Water

4.3.2.1 Calcium

Calcium ranged from a minimum value of 0 mg/L to a maximum value of 112 mg/L. The mean Calcium hardness among the tested boreholes was calculated to 102.07 mg/L. Maximum calcium levels were observed in Naivasha Boarding school Borehole (112 mg/L). Calcium level varied along sampling sites and the levels obtained were within the maximum permissible limits as advised by WHO Standard value of 250 mg/L.

4.3.2.2 Chlorides

Chloride is an anion formed when chlorine gas gains an electron. Chloride level ranged between a minimum of 0 mg/L and a maximum of 350 mg/L. Chlorides in boreholes water result from leaching of chlorides from rocks and soils and is associated with sodium in drinking water. However, maximum chloride level among the borehole was recorded at Kenya Women Holding Limited borehole with 350 mg/L. The mean chloride level among the boreholes was 65mg/L given that WHO Standards of a maximum of 250 mg/L indicates that majority of the borehole all tested sampled were within range.

4.3.2.3 Electrical Conductivity

This is the measure of how much total salts is present in the water, i.e. the more the ions present in water the higher the conductivity (Aalbersberg,2004).Electrical Conductivity tested from the borehole water points varied from 0.077 µS/cm to 2,900 µS/cm. The mean conductivity among the boreholes was 576.74 µS/cm with a maximum conductivity value detected at Julias Kinyua Kamau borehole (2,900 µS/cm). Pure water is a poor conductor of electricity. Conductivity is dependent upon the presence of ions and thus an indicator of TDS in water. As the concentration of dissolved salts, usually salts of calcium and magnesium, chloride and sulphate, increases in water, electrical conductivity increases. Electrical Conductivity guidelines given in WHO Standards is a maximum of 2500 µS/cm, thus all the tested sampled were within range except the above mentioned borehole. A study carried out by Muwanga and Barifaijo (2006) in Kinawataka stream and Ntinda industrial area also revealed that electrical conductivity in runoff from industries was exceeding the permissible limits (WHO guidelines, 2006) for electrical conductivity. The highest value of electrical conductivity recorded (2,900 µS/cm) could be due to release of nitrogenous compounds such as Nitrites resulting in high electrical conductivity (Koushik and Saksena, 1999).This is true as the higher Nitrites values(4.2 mg/L) were also observed in this borehole(Julias Kinyua Kamau borehole) which recoded higher electrical conductivity among other boreholes. It had also higher total dissolved solids (mobile cations) of 1,798 mg/L among the boreholes tested which tends to increase the electrical conductivity.

4.3.2.4 Fluorides

This is an inorganic with a chemical formula F the simplest anion of fluorine (Wells, 2008). Fluorides ranged from a minimum value of 0.02 mg/L to a maximum value of 23.3 mg/L with the mean fluoride level of 6.47 mg/L. Acceptable fluoride level guidelines given in WHO Standards is a maximum of 1.5 mg/L, thus majority of borehole water tested were beyond the range while others had minimum levels of fluoride as shown in table 4.13 below:

Borehole	**F^- Max (mg/L)**	**Borehole**	**F^- Max (mg/L)**
St.Mary's Academy	23.3	Kenya Agriculture Research BH	5.4

Mlimani Holding	18	Olij Farm BH	5.2
Marura l Estate Limited	16.3	Mirera Suswa BH	5.05
Marura Limited	14.2	Kibuyu BH	5.0
Star Farm	12.67	Maasai Mara Lodge Limited BH	5.0
Lizar Academy	12.15	Rubiri Water Project BH	4.5
Mirera Suswa	10.96	Julias Kinyua Kamau BH	4.1
Kreative Roses	10.53	Baharini BH	4.1
Kenya Women Holding Limited	10	Umoja BH	4.0
Ushirika	9.77	Munyu Primary School BH	3.9
Naivasha Boarding Pri School	9.5	Delamere No2 BH	3.9
Vegpro Delamere	8.95	Mwega Water Project	3.8
Erisken Enterprise	8.78	David Kangethe BH	3.65
Kenyajui Naivasha town	8.11	Malewa Water Project	3.6
Kennedy Oyunge	8.1	Kabatini BH	3.44
Olji Breeders	8.2	Naivasha Hindu Temple BH	3.3
Hyoung Company Limited	7.8	Delamere No1 BH	3.1
Delamere No 6	7.7	Valley Lilly School BH	3.0
Cymmit	7.7	Longonot Farm BH	2.6
Ruaraka Ducks	7.7	Maasai Mara Supa Lodge BH	2.12
Welcap Water Works	7.6	Cornerstone Preparatory	2.12
Rubiri (untreated)	7.16	Sopa Lodge BH	2.03
Heritage Resort	7	Parakash Manohar Heda	1.63
Kibuyu BH	7	Roka Trading Company Limited	1.4
Rubiri(treated) BH	6.67	Miriam Muthoni Muhiu	1.14
Vanderberg BH	6.6	Bigot Flowers Limited BH	0.9
Panda II BH	6.3	Harvest Limited BH	0.2
Interplant BH	6.3	Harishkmarr Dhirajlal Parekh BH	<0.003 mg/L
Marura BH	5.5		

Table 4.13: Boreholes and their F^- levels in Naivasha Sub County.

Records show that Roka Trading Company Limited BH(1.4 mg/L), Miriam Muthoni Muhiu(1.14 mg/L), Bigot Flowers Limited BH(0.9 mg/L), Harvest Limited BH(0.2 mg/L), Harishkmarr

Dhirajlal Parekh BH(<0.003 mg/L) had fluoride levels within the permissible limits of WHO of maximum 1.5 mg/L.

The high fluoride level in the majority of the boreholes within the Naivasha Sub-county can be as a result of the absorption of uprising, subterranean gas containing higher fluoride concentrations in areas where there have been volcanic activities (Gaciri and Davis, 1993). Issues of teeth discoloration and dental fluorosis may arise to people who consume the water regularly without any form of management measures applied to the water. Fluoride, a natural element, exists in combination with other elements as fluoride compound and is found as a constituent of minerals in rocks and soil. When the water passes through and over soil and rock formations containing fluoride it dissolves these compounds, resulting in the small amounts of soluble fluoride present in water. Mang'erere (2005)

also attested that high concentration of fluoride in an area could therefore be attributed to high in situ temperature (manifested by high hydro-geothermal) activity that results from tensional strain that may increase the solubility of mineral containing fluoride ions in the rocks .There has been a lot of geothermal activities in Naivasha Sub-county and its neighbouring areas and this may be the reason as to why most of the water collected from boreholes had high levels of fluorides.

4.3.2.5 Iron

Iron is a chemical element with symbol (Fe) with atomic number 26.It is the second most abundant metal in the Earth's crust which accounts for 5%.The levels of Iron content among the borehole water varied from a minimum of 0.0 mg/L to a maximum of 1.35 mg/L. The mean Iron level among the boreholes was calculated as 0.32 mg/L. This was more than the value given as a guideline from WHO Standards of 0.3 mg/L. Maximum iron content beyond the stipulated guidelines were detected in Hyoung Company Limited (1.35 mg/L), Vandenburg borehole (0.9 mg/L), Julias Kinyua Kamau borehole (0.63mg/L), Maasai Mara Supa Lodge (0.56 mg/L), Miriam Muthoni Muhiu (0.5 mg/L) and finally the Kibuyu borehole 0.035 mg/L). Excess Iron in water gives it an un-pleasant metallic taste, affects the colour to brownish which makes the water less attractive to consumers, and also lowers the pH, making the water corrosive to distribution pipes.

High levels of Iron above WHO limits were recorded could be due to the Iron metal chips from metal fabricating operations involving Iron scrap. Although Iron toxicity in humans is rare, they are potentially at risk from Fe exposures at higher levels (Adriano, 2001).

4.3.2.6 Manganese

This is an inorganic with a chemical symbol Mn with atomic mass of 54.93 g/mol. The levels of Manganese in the sampled water varied from a minimum of 0.0 mg/L to a maximum of 3.0 mg/L with the mean manganese level calculated as 0.34 mg/L among the boreholes. This was more than the value given as a guideline from WHO Standards of 0.1 mg/L indicating that majority of the boreholes had manganese content beyond the WHO guidelines. Maximum levels of manganese were recorded at Longonot Farm borehole (3 mg/L), Maasai Mara Supa Lodge borehole (2.2 mg/L), Vandenbug borehole, Kenya Agriculture Research borehole (0.5 mg/L), Kennedy Oyunge borehole (0.5 mg/L), Kinyua Kamau borehole (0.33 mg/L) Delamere No 2 borehole (0.2 mg/L) Kibuyu borehole (0.18 mg/L) and finally the Valley Lilly School borehole (0.15 mg/L). Furthermore, Iron and Manganese showed a similar behaviour, in fact, high concentrations of Manganese were found in the same sources where Fe was high for example in Vandenbug borehole, Maasai Mara Supa Lodge borehole and Julias Kinyua Kamau borehole . Manganese is an essential human micronutrient and most human intake occurs through consumption of various types of food. Inhalation studies linked chronic manganese intake with neurological disorders.

4.3.2.7 Nitrate

Nitrate is polyatomic ion with the molecular mass of 62 g/mol. Nitrate level determined from the various sample boreholes points ranged from a minimum value of 0.0 mg/L to a maximum value of 41.3 mg/L with the mean value of 2.11 mg/L. This indicated that the majority of the boreholes had Nitrate content within the Standards advised by WHO of 10 mg/L. Maximum Nitrate level of beyond the WHO was detected at Kenya Women Holding Limited borehole (41.3 mg/L), Hyoung Company Limited borehole (12.9 mg/L) and Delamere N0 2 borehole. High Nitrate levels may indicate pollution from fertilizers, feedlots or sewage. This applies to water collected from boreholes. Nitrate in water interferes with the body’s capacity to absorb oxygen.

4.3.2.8 Nitrite

Nitrite is polyatomic ion with the molecular mass of 69 g/mol. Nitrite level determined among the boreholes points ranged from a minimum value of 0.0 mg/L to a maximum value of 4.2 mg/L detected at Julias Kinyua Kamau borehole, however, with a mean value of 0.26 mg/L Nitrite content was determined among the boreholes. This was within the Standards advised by WHO of 10 mg/L. High Nitrites levels may indicate pollution from fertilizers, feedlots or sewage. This applies to water collected from boreholes. Nitrite ions in water interfere with the body's capacity to absorb oxygen.

4.3.2.9 Sulphate

Sulphate is polyatomic ion with the molecular mass of 96.06 g/mol. Sulphate level determined from the various sample boreholes points ranged from a minimum value of 0.0 mg/L to a maximum value of 295 mg/L detected at Kenya Women Holding Limited borehole. This was well with the stipulated Standards advised by WHO of 490 mg/L which indicated that the sulphate concentration in borehole water tested were within the permissible limits by WHO. High sulphates levels may indicate pollution from sulphates fertilizers, feedlots or sewage. This applies to water collected from boreholes. Sulphate ions in water interfere with the body's capacity to absorb oxygen.

4.3.2.10 Temperatures

This is the hotness or coldness of the water. The temperature of the sampled water varied from a minimum of 0^{o}C to a maximum of 25.6 ^{o}C. The mean temperature was calculated as 5.65 ^{0}C. This was good the value given as a guideline from WHO Standards of 30 ^{o}C. Higher water temperatures interfere with the water chemistry thus lowering water quality and makes water unpleasant for drinking.

4.3.2.11 Phosphate

Phosphates are polyatomic ions with the molecular mass of 94.97 g/mol. The levels of phosphates in the borehole water varied from a minimum of 0.0 mg/L to a maximum of 0.53 mg/L. The mean phosphates level was calculated as 0.06 mg/L. This was well within the Standards advised by WHO a maximum of 0.1 mg/L. Excess phosphates in water gives it an un-pleasant taste, affects the colour to brownish which makes the water less attractive to consumers. Phosphates enter waterways from human and animal waste, phosphate rich bedrock, wastes from laundry cleaning and industrial processes, and fertilizer runoff (Aalbersberg, 2004).

4.3.2.12 pH

pH is a measure of the level of activity of hydrogen ions in a solution, resulting in its acidic or basic quality. It is measured on a logarithm scale that typically ranges from 0 (acidic) to 14 (basic) with 7 being the neutral. The pH level of the borehole water tested varied from a minimum of 0.0 to a maximum of 8.8. The mean pH level value among the boreholes was calculated as 7.35. This mean value is within the WHO guideline for water pH of between 6.5-8.5 range. This may imply that majority of the water boreholes were slightly basic.

4.3.2.13 Alkalinity

Alkalinity is a function of bicarbonate, carbonate and hydroxyl ions which have dissolved from chemical compounds from rocks and soils. Alkalinity in water has no health significance but high levels makes water unpalatable and may affect the efficiency of certain water treatment processes such coagulation where treatment is needed. According to the set standards (6.5-8.5), all the tested samples fall within range and satisfy alkalinity requirements. Alkalinity level determined from the various sample boreholes points ranged from a minimum value of 0.0 mg/L to a maximum value of 1,260 mg/L with the mean value of 348.9 mg/L. This indicated that the majority of the boreholes had alkalinity content within the Standards advised by WHO of 500 mg/L. Concentration of alkalinity beyond the WHO were recorded at Kenya Women Holding Limited borehole (1,260 mg/L), Mwega Water Project borehole(1,218 mg/L), Olji Breeders(848 mg/L), Naivasha Hindu Temple (825 mg/L),Vandeberg Borehole (719 mg/L),Kennedy oyunge borehole(684 mg/L) Delamere No 2 borehole(616 mg/L) Rubiri Water Project borehole(572 mg/L) and Milimani Holding boreholes (564 mg/L).

4.3.2.14 Total Hardness Observable (THO)

This is the natural characteristics of water which can enhance its palatability and consumer acceptability for drinking. Total hardness ranged from a minimum of 0.0 mg/L to a maximum of 223 mg/L. The mean total hardness among the borehole water investigated was found to be 56.97 mg/L. Hardness is the soap consuming capacity of water; that is, the more soap required to produce lather, the harder the water. From the determined values it can be inferred that the majority of the boreholes had hard water as the values have surpassed advised value of 5.0 mg/L in the WHO Standards except where THO was not detected (0.0 mg/L) in Kibuyu borehole, Delamere No 1,Hyoung Company Limited borehole and Julias Kinyua Kamau borehole.

4.3.2.15 Orthosphate

Orthosphate concentration ranged from a minimum of 0.0 mg/L to a maximum of 0.33 mg/L. The mean orthosphate among the borehole water investigated was found to be 0.02 mg/L. Higher values were detected at Maasai Mara Supa Lodge borehole (0.33 mg/L).No stipulated guidelines for Orthosphate content in water by WHO.

4.4 Human health implications associated with drinking groundwater with high level Fluoride

The study sought to establish whether human beings have health implications associated with drinking underground water with extreme levels of fluoride. When requested to indicate if any of their family member was a victim resulting from consumption of high fluoride, 60.6% who represented the majority agreed while the rest of the majority 39.4% disagreed that any member of their family was a victim due to intake of high fluoride. The results are shown in the figure 4.11 below.

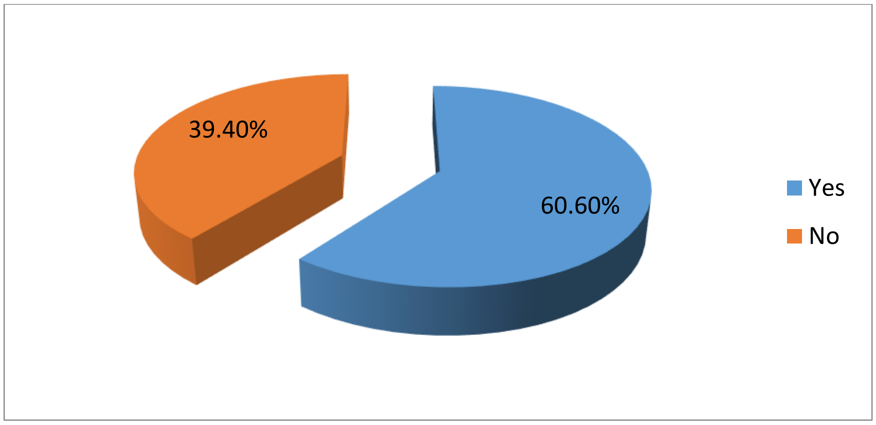

Figure 4.11: Victims of High fluoride consumption.

Among the 60.6% of the victims of fluorosis, the research study was determined to know how the fluorosis in the affected victims presented itself. Variables under investigation in this section were dental fluorosis, skeletal fluorosis and both dental and skeletal fluorosis. Results obtained are as follows;

Presentation of Fluorosis	Frequency	Percentage (%)
Dental fluorosis	139	71.52
Skeletal fluorosis	37	19.67
Both dental and skeletal fluorosis	17	8.81
Total	**193**	**100**

Table 4.14: Presentation of Fluorosis

From the data analyzed in table 4.14 above, it is clear that few respondents agreed that fluorosis presented itself as both in dental and skeletal fluorosis. However 71.52% and 19.67% of the respondents indicated that fluorosis presented itself as dental fluorosis and skeletal fluorosis respectively.

Figure 4.12: A photograph showing a victim of dental fluorosis in Hells'gate Ward, Naivasha Sub County.

The researcher explored the local shops and supermarkets and this are the common toothpastes on display;

	The type of toothpaste available in Naivasha Sub County	**Fluoride Levels in the Toothpaste**
1.	Whitedent herbal fluoride toothpaste	0.76% sodium monofluorophosphate
2.	T – guard toothpaste	Sodium fluoride (1000ppm of fluoride)
3.	Dabur Miswak	Fluoride free toothpaste
4.	Smokers' toothpaste	Fluoride free toothpaste
5.	Aloe toothpaste	Fluoride free toothpaste
6.	Dana fluoride toothpaste	Sodium monofluorophosphate 0.76% Max
7.	Aquafresh milk teeth toothpaste	Sodium fluoride 0.1106% (500ppm of fluoride)
8.	Pepsodent toothpaste	Sodium monofluorophosphate (1450ppm of fluoride)
9.	Close up deep action toothpaste	Sodium fluoride (1450ppm fluoride)

10.	Aquafresh big teeth toothpaste (6 – 8 yrs)	Fluoride 1450ppm
11.	Aquafresh fresh and minty	Sodium fluoride 0.315% w/w (1450ppm of fluoride)
12.	Sensodyne with fluoride	Sodium fluoride 0.315% w/w (1450ppm of fluoride)
13.	Parodontax	Sodium fluoride USP 0.31% w/w
14.	Colgate herbal	Sodium monofluorophosphate 1.1% (1450ppm of fluoride)
15.	Colgate natural extracts	Sodium fluoride 0.22% w/w (1000ppm of fluoride)
16.	Dabur Herbal natural toothpaste	Fluoride free toothpaste

Table 4.15: The type of toothpastes available in Naivasha Sub County

Considering that borehole water in Naivasha already has high fluoride, Out of the 16 types of toothpaste available in Naivasha Sub County stores, only 4 types are fluoride free. Dental fluorosis is not only natural but also provoked through the majority of the fluoride containing toothpastes provided for, in the local stores. Education on toothpaste safety is required.

On coping mechanisms adopted by the individuals within Naivasha Sub County, the participants were requested to choose one of the mechanisms under research investigation. The information obtained is tabulated in Table 4.16 below.

Coping mechanisms	**Frequency**	**Percentage (%)**
Drinking rain water	39	20.26
Drinking treated water	10	5.23
Buying treated water	4	2.13
No mechansims adopted	97	49.05
None of the above mechanism	3	2.59
Boiling water	19	10.20
Buys dispenser water when money is available	4	1.71
Brushing teeth	14	7.23
Buying ATM water when able to afford	1	0.55

Dental masking	2	1.05
Total	**193**	**100**

Table 4.16: Coping mechanisms.

From the data analyzed above, 2.59% of the respondents never used any of the provided mechanism to cope up with fluorosis while buying of treated water was embraced by 2.13% individuals, drinking of treated water by 15.23% of the respondents .Majority of the respondents who constituted 49.05% and 20.26 % affirmed that they never used any coping mechanism and drinking of rain water as a strategy to combat the adverse impacts of fluorosis. Those who boiled water were 10.20%, those who brush the teeth incorporated 7.23 % and 1.71% ascertained that they bought dispenser water when money is available. Individuals who bought ATM water when able to afford and those who practiced dental masking were 0.55% and 1.05% respectively. The research investigated the average rainfall distribution for the study are to assess its viability as one of the coping mechanisms that the residents can use the harvested water by the use of storage facilities to store the rain water and avoid frequent consumption of fluoridated water.

The figure 4.13 below shows the pictorial representation of the average rainfall for the study area from year 2008 up to 2018.

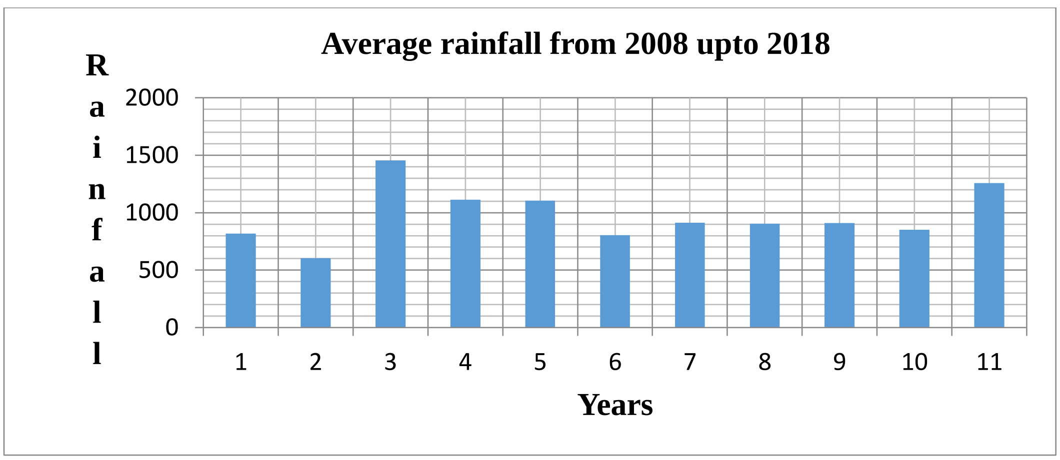

Figure 4.13: Average rainfall.

Rainfall data (see appendix 6) shows that Naivasha Sub-county received a mean rainfall of 975.89 mm every year which is sufficient to be harvested by the residents within the area as the coping mechanisms for defeating fluorosis using the storage water facilities.

4.4.1 The suitability of water blending in Lowering Fluorosis.

An experiment was conducted to determine the current levels of fluoride in groundwater rich in fluoride and levels of fluoride after blending it with harvested rain water (Figure 4.14 below).

Figure 4.14: Water Blending as a suitable method of defeating fluorosis.

The researcher collected 3 water samples as representatives of the 3 types of water (rainwater, high fluoride water and blended water). The researcher took the water samples to the the Rift Valley Water Works Development Agency lab in Nakuru County for Fluoride analysis. To determine the level of fluoride ions in the water samples, an SPADNS reagent and photometer was used (Delhi, 2000). The following are the results (Figure 4.15).

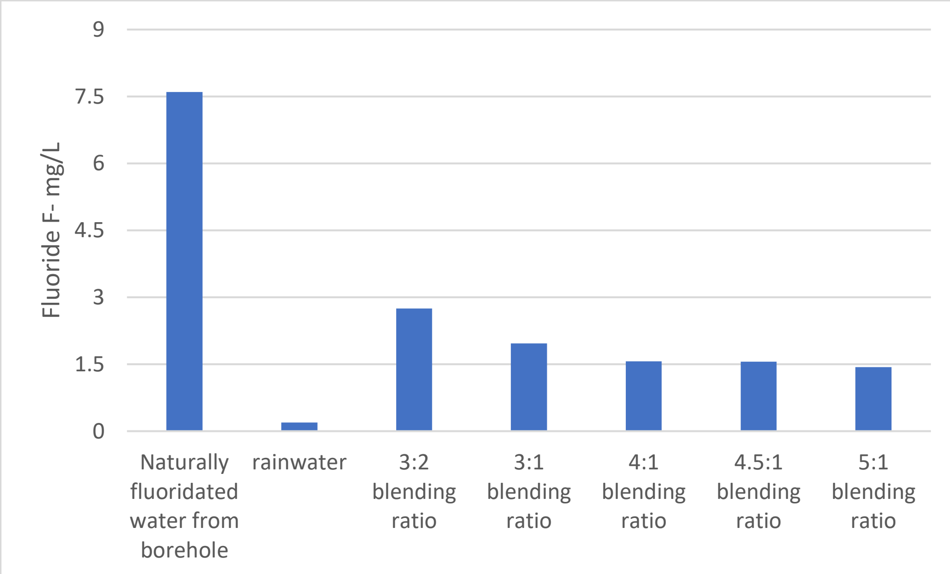

Figure 4.15: Type of water and blending ratios to achieve optimum blending ratio

Figure 4.15 reflect the extent of reduction of fluoride concentration in borehole water using the water blending technique. These findings prove that water blending is effective for reducing fluoride concentration in water as fluoride was diluted to the recommended WHO nontoxic level of below 1.5mg/L.

Awareness of the research respondents to any traditional method to treat or keep water clean for drinking was another desire for the research study. The individuals were requested to indicate the traditional method they used to make the water clean or safe for drinking and the analyzed data on this parameter showed that majority of the respondents (35.76%) used boiling as a traditional method of treating water. The study also revealed that 23.32% and 27.46% of the respondents responded that none of the concerned traditional methods and no traditional method of treating or cleaning water they used respectively. Those who used charcoal, certain stones, filtering and decanting, cleaning the container for boiled water, use of ash and putting sand were 1.92% of the respondents in each case as shown in table 4.17 below.

Traditional method of treating/cleaning drinking water	**Frequency**	**Percentage (%)**
Boiling	69	35.76
Adding chlorine and water guard	4	1.92
Use of charcoal	4	1.92
Use of certain stones	4	1.92
Filtering and decanting	4	1.92
Boiling and keeping in a clean container	4	1.92
Mixing the fluoridated water with ash	4	1.92
Putting sand in water	4	1.92
No traditional method for water treatment	52	27.46
None of the method above	44	23.32
Total	**193**	**100**

Table 4.17: Traditional Methods of treating/cleaning drinking water.

CHAPTER 5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter contains the discussion, conclusions and recommendations of the research. It will also have suggestions for further study.

5.1 Discussion

The study was intended at defeating fluorosis in rural Kenya specifically in Naivasha Sub-county of Nakuru County. It sought to identify the awareness of people about the existence of fluoride in water, treatment of drinking water by people and local water suppliers, availability of shops selling treated water or products for water treatment, health effects of drinking water with higher levels of F^- and determining the water quality by investigating the water chemistry among the water samples obtained in different boreholes at Naivasha Sub-county. The data was collected using questionnaires and analyzed using descriptive statistics and presented using frequency tables, pie charts and bar-graphs.

5.1.1 General Information

The study found out that the majority of the respondents, (64.3%) who constitute the households members responded to the questionnaires as expected. The study was determined to investigate the education levels of the respondents because the education attained by the individual was a crucial variable in awareness about the effects that results from the consumption of high fluoride water.

The research investigated the respondents' education as far as the education on fluoride was considered; the research findings revealed that the majority of the respondents have not been educated about fluoride, water safety and how to cope with it.

On water treatment, the research revealed that majority (57.14%) of the local supplier never treated water before supplying to the local population, reason being the unavailability of treatment systems within the area.

The availability of shops selling water treatment products or treated water within Naivasha Sub-county was an important factor which determined the number of individuals who treated water before use. 64.8 % of the respondents indicated that there was unavailability of shops selling water treatment products. Majority of the respondents (78.76%) never treated their drinking water. On water utilization, (66.32%) of the respondents indicated that water used for drinking was not different from that used for cooking and for irrigation.

5.1.2 Supply sources of drinking water in Naivasha sub-county.

Majority (48.70%) of the respondents indicated that drilled well within the area of residence supplied them with water for drinking. 24.87 % of the respondents responded that they obtain their drinking water from individually rain harvested sources.

When the respondents were asked about their take on rain harvesting pack for the whole community, majority indicated that there was value in a RWH park.

Proximity to the water source (water kiosk) was determined and only 35.24% (68) of the respondents indicated they were close to water sources while majority of the respondents 64.76% (125) were far away from their sources of water.

The study sought to find out the cost per unit charge of water in which the residents within Naivasha Sub-county obtained water for use from the local suppliers (water kiosk). From the findings of the study, majority of the respondents representing 23.3 % (45 respondents) indicated that they bought water for 20 shillings (0.19 USD) per 20 litres containers.

The study also revealed 82.39% of the respondents agreeing that water from their local sources was not readily available due to water blackouts. When the same question about the occurrence of the water blackout was directed to the local suppliers of water, 71.4% of the water supplier indicated that there was water black out due to higher water demand in the area.

The study interrogated the respondents about the communication forum of sharing information between them and water supplier. Research results revealed that majority of the respondents 92.22% indicated there was no communication forum.

5.1.3 The quality of the drinking water from boreholes within Naivasha Sub-county.

The second objective of the study was to determine the quality of drinking water among the boreholes within the Naivasha Sub-county. The quality of water from the various boreholes was assessed in terms of its physical and chemical characteristics.

Fluorides ranged from a minimum value of 0.02 mg/L to a maximum value of 23.3 mg/L. Majority of the borehole water tested were beyond WHO's permissible limit while others had minimum levels of fluoride. Roka Trading Company Limited BH (1.4 mg/L), Miriam Muthoni Muhiu (1.14

mg/L), Bigot Flowers Limited BH (0.9 mg/L), Harvest Limited BH (0.2 mg/L), Harishkmarr Dhirajlal Parekh BH (<0.003 mg/L) had fluoride levels within the permissible limits of WHO of maximum 1.5 mg/L. The high fluoride level in the majority of the boreholes within the Naivasha Sub-county can be as a result of the absorption of uprising, subterranean gas containing higher fluoride concentrations in areas where there have been volcanic activities (Gaciri and Davis, 1993.)

5.1.4 Human health implications associated with drinking the groundwater with high level Fluoride

The study sought to establish whether human beings have health implications associated with drinking groundwater with extreme levels of fluoride. 60.6% represented the majority respondents, whose family members are victims of fluorosis resulting from consumption of water with high fluoride. 71.52% of the respondents indicated that fluorosis presented itself as dental fluorosis.

The research study also aimed at investigating the coping mechanisms adopted by the individuals within Naivasha Sub County. Majority of the respondents who constituted 49.05% affirmed that they never use any coping mechanism and drinking of rain water is the only strategy to combat the adverse impacts of fluorosis.

5.2 Conclusion

Based on the findings of this study it can be concluded;

- That the borehole water within Naivasha Sub-county has exposed the residents to higher fluoride levels.
- There is a lack of professional help in terms of water safety. The education system has not been able to create awareness on fluorosis in Naivasha Sub-county as most of the residents who were knowledgeable on fluorosis were few and the larger populations were affected by fluorosis.
- There were few shops selling the water treatment products to the residents and local water suppliers providing the residents with clean and safe drinking water.
- All the water from the sampled boreholes was good aesthetically; that is, the water quality was good with reference to aesthetic quality parameters like, turbidity, calcium, chloride, conductivity, phosphate and total dissolved solids apart from tested

parameters that were not within the recommended specifications such as alkalinity, fluoride, water rest level, iron, sulphate, manganese, Nitrate, Nitrites, total hardness observable and temperature.

- There is no reliable representative data on drinking water quality in the rural areas of Naivasha Sub County. Where data exist, it is not adequate to be considered as legitimate representative of the drinking water quality and may therefore underestimate water safety.
- Taking into account the unique challenges faced by fluorosis affected communities, Fluoride situation has special needs that needs to be taken account of. Water laws need to be more inclusive, cohesive, leaving no one behind making sure every element is covered, ensuring fluoride issues are being integrated and included in a more particular manner. There's a need for a unique model to be designed, to cover for fluorosis affected communities. The water laws need to take fluorosis affected communities more and very seriously.
- Water blending is needed in Naivasha sub County, as an option to secure the supply of safe, good quality and adequate potable water to the populations and to meet the rapid increase of demand for water in agriculture and industry sectors.
- The success of service delivery projects and partnerships in the water sector is crucial and dependent on good leadership, professional, dedicated and disciplined workforce as well as the policies in place because effective leadership, laws, policies and plans are the enablers of a good working environment and has a direct impact on the success of water resources management and development as well as the implementation of projects.
- With the right interventions and commitments in place, the researcher foresees a generation of children who are not suffering from dental or skeletal fluorosis due to the availability of water with dignity in fluorosis affected communities.

5.3 Recommendations

Based on research findings, the study therefore prescribes the following fluoride eradication recommendations;

5.3.1 General Recommendations

- GIS and remote sensing should be developed, maintained and used by the Ministry of Water and Irrigation as well as the Water Resources Authority for delineating comprehensively fluoride levels in water distribution in Naivasha area and the whole Kenya. GIS and remote sensing will provide an efficient, accessible, retrievable and well managed water quality database. This database may be used to provide baseline data that may be used to model water quality in Naivasha Sub-county. The data system may also help while undertaking studies like change-detection analysis and water quality monitoring.
- WASREB should come up with clear-cut and tight measures of ensuring that people who abstract water from boreholes have complied with the standards specified in the Kenya Drinking water quality standards and that of WHO safe water standards.
- Raw sewer and dumping of high level chemicals from agricultural farms, from as far as Kinangop Sub County through river Malewa, leaving Lake Naivasha, the only fresh water lake around intoxicated with Nitrates that are normally not easy to treat, and groundwater fluoride toxicity being a harsh reality for the local population in Naivasha Sub County; this situation calls for an all-round discussions and actions that will ensure provision of safe consumption water for the locals in Naivasha Sub County.
- It is tenable to think and consider Making mount Longonot a wildlife proofed RWH Park and a water tower by the establishment of a community championed and community owned rain water harvesting park inside the depression in the mountain, to gravity feed especially the people in informal settlements who cannot collect rainwater from their roofs.
- The fight against fluorosis gets modest attention, modest eradication efforts and quick fixes but it's a fight that requires heavy and long-term investments. There is a need to invest heavily in public health infrastructure when it comes to fluoride eradication; a) Water treatment systems to be installed strategically for every ward in Lake Naivasha, (b) investments in water storage tanks, customized water towers and places to store usable rainwater, (c) investments in rainwater harvesting systems. This investments will ensure that safe and good quality water is available in sufficient quantities and on a constant basis. The water will also be useful during dry season.

- There is need to manage the quality of water especially groundwater in terms of reducing fluoride levels where they have exceeded 1.5 mg/L. This is so as to safeguard human health and in such cases, private operators who rely solely on groundwater supply, should adopt water blending so as to combat fluorosis at its source, if the local drinking water suppliers desire to supply it for drinking purposes.
- Sensitization of the public on the need to use surface water and rainwater as alternative water sources as well as embracing water blending to prevent cases of dental and skeletal fluorosis.
- There is need for the humanitarian assistance to have a skill component. The government, private sector and the donor funders should start designing and implementing more sustainable programmes, models and innovations that will enable universal safe water provision.
- In order to free the affected communities of fluorosis, participation of all stakeholders and resources investments is required. Community based organizations need to be given the enabling leverage (smarter subsidies for water) to free themselves of fluorosis. This will renew support and hope in the communities.
- Carry out faster implementation of concrete and scalable interventions that are outside the implementers' comfort zones to enhance resilience in Naivasha and for the people to be civilized from fluorosis.
- As a catalyst for community action, implementation of a decentralized approach, where the communities run with their own agenda by registering social enterprises that are geared towards defeating fluorosis. The social enterprises to work with the government water institutions / humanitarian assistance that deals with community organizations and for this approach to be a platform for education on water safety as well as accelerating the process of implementation of the possible solutions.
- Up scaling of the local initiatives already in place, geared towards fluorosis eradication. Engaging the newly registered and the already established community social enterprises constructively, for them to be made empowerment channels through which each household would be assisted in owning gutters and water tanks (10,000 litres storage). Each household to register with a commitment fee that will be part of procuring the storage systems.

- A timeframe should be given, as to what time and when the community initiatives in partnership with the government and funders have, to achieve the goal of buying each household water storage tanks and gutters in the rural areas, the construction of the rainwater harvesting park on mount Longonot to supply the informal settlements and lake Naivasha water treatment systems establishment, to ensure safe and good quality water supply for domestic use to the different wards of Naivasha sub county.
- Implementation of initiatives aimed at informing people. Capacity building and education on water safety to improve fluorosis eradication wisdom. Communities and households to be trained on how to come up with home policies that ensure water safety.
- Fluorosis eradication to be considered a priority. It is necessary to build consensus prior to implementation of water resources development projects in fluorosis affected communities. CGN to ensure partnerships with community owned social enterprises that will result to normalized fluorosis eradication interventions and public health initiatives in the area. This will also ensure that rent seekers are closed out.
- Establishment of research and innovation centers with equipped community labs in fluorosis affected communities for availability of fluorosis lab services to be no longer a rarity.
- There’s a need for prudent financial management comprising of budget and expenditure tracking to ensure accountability in the use of WASH money and so as to also ensure the money is not unfairly misappropriated.
- Through corporate accountability, Mobilize Dentists associations in Kenya to volunteer and do composite masking as well as improving the locals’ wisdom on toothpaste safety in fluorosis affected communities to give the rural people a reason to smile confidently, ensure their self-esteem is restored and to improve their health psychologically.
- More publicity on hydrofluorosis and the solutions should be given to the general public and even more to the target group of funders, Governments, NGO’s, consultants, researchers, who work in areas in developing countries facing this problem.
- Development and innovation of household fluoride monitoring gadgets so as to enable households to personalize fluoride monitoring and so that the locals can have the power to know the fluoride concentrations in their water before consuming it.

- Attitudinal solutions. A change in mindsets, about reaching the rural areas with water supply. Currently, sizeable number is what determines whether the rural remote communities will be connected to a safe and good quality water supply. Naivasha Sub County being a goldmine for revenue, humanity should precede the revenues quest. It's the communities who should be benefiting more from the revenue generated.
- The government mandated local water utility to consider approaches geared towards serving a wider community through a network of water kiosks that are easily accessible, strategically placed, adequate in number and in storage capacity to serve throughout the Naivasha settlement.
- Rainwater being intermittent by nature, rainy season volumes need to be harnessed, collected and stored. Run off water in Maiella ward and other parts of Naivasha needs to be harnessed and dammed effectively in order to contain the flow because most areas in the sub county have vulnerable soils; this will also curb soil erosion as a result.
- Mobilizing political will, creating awareness and securing commitment among all with regard to water issues, including appropriate gender and youth involvement. For decision makers and legislators to ensure all households have water with dignity on premises.
- Investigations on what the small aircraft from the local flower farms that have been accused by the residents of Hells gate ward, of air spraying targeting rain bearing clouds hence modifying the local climate should be done, to establish what the aircraft's business is, near the rain bearing clouds when it's about to rain.

5.3.2 Policy Propositions;

- Fluorosis is a multi-country issue in the African continent but there is no continental considerations made towards fluorosis control efforts. There's a need for formulation and implementation of smart, targeted and efficient African ground water policies towards fluorosis eradication, given the most severe fluoride belt is in the African continent. The policies to be encoded and localized differently depending on the context of the country.
- The legislative to give legal right to safe water provision in Naivasha through the implementation of integrated policies between water and energy that will ensure community water projects are offered cheap electricity and water solutions, because the area is geothermal rich and Mount Longonot being the reason behind the geothermal

potential is also the reason behind high fluoride aquifers in the area as a result of its previous volcanic activities.

- Calling on the Kenyan government to invest more on the implementation of pro poor policies and formulation of children sensitive national plans as well as groundwater governance policies responsive to children's public health safety, to ensure that they work and deliver for the most vulnerable and to make the early moments matter for every child.
- Policies to be put in place to ensure the revenues collected from the multimillion horticultural industry, tourism, fishing, and geothermal exploitation in Naivasha reflect on the thriving capacity of the local population, making sure there is a balance and the local human resource is not just being exploited.
- Formulation of transformative policies and implementation of programmes that are geared towards ensuring water supply is adequate and universal in Naivasha.
- Formulation of policies that will ensure KenGen, the hoteliers and local flower farms practice corporate accountability and have a role to play in terms of safe water provision in the rural areas besides paying their revenues to the government.
- A policy should be put in place that ensures institutionalization of consumer voice by the establishment of a platform for handling consumer complaints and grievances. Presence of ICT forums will encourage information sharing and the possibility of messaging consumers so as the local water suppliers get to reach a mass of households at the touch of a button. This will also apply to solving the conflict between the road network constructors and the local water network establishment and construction. Communication will also be key in information sharing and scaling up awareness regarding effective fluorosis eradication.
- Implementation of the public participation policy on matters water, whereby the locals, right from the lower level of the wards, are able to participate in decisions that directly affect them.
- Formulation and harmonization of community, institutional (government), market (profit making logic), political, faith based policies and all the other minor and major rules governing Naivasha sub county to ensure that when a project is introduced and implemented, it does not disrupt the system, for the durability and sustainability of projects.
- Formulation and implementation of public health and medical policies aimed at the mitigation of hydro fluorosis in FAC.

This study further recommends that, more studies be done to determine the fluoride levels in borehole water utilized by residents in various fluoride prone regions of Africa with a special focus on arid and semi-arid areas. There's a need for a sustainability report to be done, to assess the impact of the already implemented fluoride eradication programmes on the livelihoods of beneficiaries, particularly on how sustainably the quality of life of individual persons have been improved when it comes to defeating fluorosis. Comprehensive research should be done to estimate the number of children under the age of 10years, who live within fluorosis affected communities and constantly consume water from unimproved groundwater sources that could be at the risk of dental and skeletal fluorosis. More extensive research on the number of people depending on groundwater with higher contents of fluoride should also be done. There's another whole world to discover in terms of the consequences of using high fluoride water for bathing, effects of fluoride topically, besides when ingested in terms of causing acne and how it affects the skin pH.

CHAPTER 6. REFERENCES

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CHAPTER 7. APPENDICES

Appendix 1: Ethics research permit from NACOSTI Kenya

THIS IS TO CERTIFY THAT:
MISS. RUTH WAMBUI WAGATUA
of PAN AFRICAN UNIVERSITY INSTITUTE FOR WATER AND ENERGY SCIENCES (PAUWES), TLEMCEN, ALGERIA, 0-200 Nairobi,has been permitted to conduct research in *Nakuru County*

on the topic: *DEFEATING FLUOROSIS IN RURAL KENYA USING THE KILIMANJARO CONCEPT: A FEASIBILITY STUDY IN NAIVASHA*

for the period ending:
12th April,2020

Permit No : NACOSTI/P/19/06364/29327
Date Of Issue : 12th April,2019
Fee Recieved :Ksh 1000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014.

CONDITIONS

1. The License is valid for the proposed research, location and specified period.
2. The License and any rights thereunder are non-transferable.
3. The Licensee shall inform the County Governor before commencement of the research.
4. Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies.
5. The License does not give authority to transfer research materials.
6. NACOSTI may monitor and evaluate the licensed research project.
7. The Licensee shall submit one hard copy and upload a soft copy of their final report within one year of completion of the research.
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice.

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CONDITIONS: see back page

Appendix 2: NACOSTI Research Authorization Letter

**NATIONAL COMMISSION FOR SCIENCE,
TECHNOLOGY AND INNOVATION**

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2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref. No. **NACOSTI/P/19/06364/29327**

Date: **12th April, 2019**

Ruth Wambui Wagatua
Pan African University Institute for
Water and Energy Sciences (PAUWES)
ALGERIA.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Defeating fluorosis in rural Kenya using the Kilimanjaro Concept: A feasibility study in Naivasha"*** I am pleased to inform you that you have been authorized to undertake research in **Nakuru County** for the period ending **12th April, 2020.**

You are advised to report to **the County Commissioner and the County Director of Education, Nakuru County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nakuru County.

The County Director of Education
Nakuru County.

National Commission for Science, Technology and Innovation is ISO9001:2008 Certified

Appendix 3: DCC – Naivasha Sub County Office Research Authorization Letter

OFFICE OF THE PRESIDENT
MINISTRY OF INTERIOR AND COORDINATION
OF NATIONAL GOVERNMENT

Telegrams: DISTRICTER" Naivasha
Telephone: Naivasha 050-2020014
Email:dcnaivasha@gmail.com
When replying please quote

THE DEPUTY COUNTY COMMISSIONER
NAIVASHA SUB-COUNTY
P.O. BOX 11
NAIVASHA

Ref No **CORR.3/4 VOL.I/(242)**

7th May, 2019

TO WHOM IT MAY CONCERN
NAIVASHA SUB COUNTY

RE: RESEARCH AUTHORIZATION

Ruth Wambui Wagatua is authorized to carry out a research on **"Defeating Fluorosis in rural Kenya using the Kilimanjaro concept: A feasibility study in Naivasha."**

Kindly give all the assistance needed to make the same a success.

Thank you.

MBOGO MATHIOYAH
DEPUTY COUNTY COMMISSIONER
NAIVASHA SUB-COUNTY

DEPUTY COUNTY COMMISSIONER
P.O. BOX 11 - 20117
NAIVASHA

Appendix 4: Questionnaire for households

Introduction:

My name is Ruth Wambui WAGATUA; a student at Pan African University, Institute of Water and Energy Sciences. I am conducting a research to investigate the occurrence of fluoride in groundwater, severity of fluorosis on the local population and also to find out the frugal remediation strategies that can be implemented in order to defeat fluorosis in the rural areas. Kindly fill this questionnaire for me, it will take approximately 30 minutes. The results will be treated anonymously.

Consent: Do you agree to participate in the study? Yes ☐ No ☐

Section 1:

1. **General Information:**

Survey Identification Data

Questionnaire Code.		Date:		Start Time:	
Enumerator's Code					
Community		Section		House No.	
GPS Code	Latitude		Longitude		
Name of Respondent *(optional)*		Sex of Respondent	M ☐ F ☐		

	No formal education	Primary	Secondary	Tertiary
a. Level of education				

	18-25	26-30	31-35	36-40	41-45	46 and above
b. Age of respondent						

	Male	female

c. Gender		

	Yes	No
d. Have you been educated about fluoride, it's consequences and how to cope before?		

	Regularly	Not regularly	Never
e. Do you currently treat your drinking water?			

f. If yes, what methods are you using to treat the water?
....
....

g. If no, then why don't you treat your water?
....
....

	Yes	No
h. Where you live there are shops that sell water treatment products/ treated water		

	Yes	No
i. Your drinking water is different from your cooking and irrigating water		

	Individually Rain harvested	Individually drilled well (shallow/deep boreholes)	Local supplier	Shops that sell treated water
j. Who supplies your drinking water?				

k. Who typically collects the water for the household?

1. Women
2. Children (girls only)
3. Children (boys only)

4. Children (all)
5. Women and children (girl)
6. Women and Children (boy)
7. Women and Children (all)
8. Men
9. Men and Children
10. Men and Women
11. Entire family, anyone may go to fetch water
12. The water is piped/ connected to the household

	Yes	No
l. Is the available water adequate?		

	Yes	No
m. Is any of your family members a victim of high fluoride consumption?		

n. If yes, how many? How old?

	Dental fluorosis	Skeletal fluorosis
o. If yes, how is the fluorosis presenting itself?		

p. What are the coping mechanisms you have adopted?

q. Are you aware of any traditional methods to keep water clean or to clean/treat drinking water?

r. If yes explain the method or material used in cleaning or treating the water before using?

s. What do you know about rainwater harvesting technology?

t. Do you experience water blackouts from your supplier?

u. Is there a communication forum for information sharing between you and your water supplier?

v. How much per unit charge?

w. How would you take rain water harvesting for the whole community?

Appendix 5: Questionnaire to experts

Introduction:

My name is Ruth Wambui WAGATUA; a student at Pan African University, Institute of Water and Energy Sciences. I am conducting a research to investigate the occurrence of fluoride in groundwater, severity of fluorosis on the local population and also to find out the frugal remediation strategies that can be implemented in order to defeat fluorosis in the rural areas. Kindly fill this questionnaire for me, it will take approximately 30 minutes. The results will be treated anonymously.

Consent: Do you agree to participate in the study? Yes ☐ No ☐

	Regularly	Not regularly	Never
a. Do you currently treat your water before supplying to the local population?			

b. If no, then why don't you treat your water?

1. Treatment systems are not available
2. I feel that it is ineffective
3. The water from the source is very clean
4. Treatment technology is too expensive
5. No other supplier in my community treats water, hence I don't treat it too
6. My forefathers never treated the water from this source hence why do I need to?

c. Would you kindly give us your thoughts on possible improvements that can be implemented to reverse the situation?

d. What is your opinion about rainwater harvesting technology for domestic purposes?

e. Are there water blackouts?

f. Is there a communication forum for information sharing between you and your customers?

g. How much per unit charge?

h. How would you take rain water harvesting for the whole community?

Appendix 6: Enumerators' Service Provision Agreement

This agreement is entered between WAGATUA Ruth and ……………………………………………….
of ID NO: ……………………………………………….   Tel No.………………………………………………………..

Thus you have been engaged to collect data for the project: *"Defeating fluorosis in Rural Kenya using the Kilimanjaro Concept: A feasibility study in Naivasha"*

Your Responsibilities

That you will be expected to diligently administer questionnaires to collect data

Ruth Wambui WAGATUA's Responsibilities:

Shall remunerate you, KES ______________ per day on completion of the works given upon advice by the research supervisor.

Shall monitor the work undertaken and scrutinize the service rendered

Exclusion Clause

Ruth Wambui will not be liable; either wholly or in part to accidents that may occur during your service provision.

This agreement will cease to exist after completion of the exercise.

Approvals

Name: ………………………………………………………

Date: ……………………………………………………….

Witness:

Name: ……………………………………………………..

Date: ………………………………………………………

Acceptance

I ……………………………………………………………   of ID NO. ……………………………………………………………..

Have read and understood the terms and conditions as stated in this agreement and have agreed to abide by them.

Sign ……………………………………………….   Date ………………………………………………………….

Appendix 7: Daily Worksheet & Cash Acknowledgement

DAILY WORKSHEET & CASH ACKNOWLEDGEMENT FOR DATA COLLECTION FOR "*Defeating fluorosis in rural Kenya using the Kilimanjaro Concept: A feasibility study in Naivasha*"

Date						
Signature						
Date						
Signature						
Date						
Signature						
Date						
Signature						

CASH ACKNOWLEDGEMENT

NAME	ID NO	TELEPHONE NO	AMOUNT RECEIVED

Paid by: ………………………………………………………… Sign ……………………………………………… date: ……………………………………………

Witnessed by: ……………………………………………… Sign ……………………………………………… date: ……………………………………………

Appendix 8: Rainfall distribution of Naivasha Sub-county from year 2008 up to 2018

Year	**Average rainfall (mm)**
2008 represented as 1	817
2009 represented as 2	603.56
2010 represented as 3	1454.85
2011 represented as 4	1112.37
2012 represented as 5	1,103.90
2013 represented as 6	805.57
2014 represented as 7	913.36
2015 represented as 8	905.03
2016 represented as 9	910.49
2017 represented as 10	851.34
2018 represented as 11	1257.38
Mean Rainfall per Year	**975,89**

Appendix 9: Type of water and blending ratios to achieve reliable water quality

Type of water	**F- mg/L**
Naturally fluoridated water from borehole	7,6
rainwater	0,2
3:2 blending ratio	2,75
3:1 blending ratio	1,97
4:1 blending ratio	1,57
4.5:1 blending ratio	1,56
5:1 blending ratio	1,44

APPROVAL SHEET

This proposal has been submitted with our approval as University Supervisors;

Supervisor

Signature: .... Date: ....

Professor Jabulani R. Gumbo

Department of Hydrology and Water Resources Mining and Environmental Geology

University of Venda, South Africa

Co-Supervisor

Signature: .... Date: ....

Dr. Tulinave Mwamila

Head, Research and Consultancy Department,

Water Institute, Ministry of Water, Tanzania

Co-Supervisor

Signature: .... Date: ....

Dr. Chicgoua Noubactep

Department of Applied Geology

University of Göttingen, Germany