UNIVERSITY OF NAIROBI

ASSESSMENT OF DRINKING WATER QUALITY FOR RESIDENTS OF KURIA WEST IN MIGORI COUNTY

BY

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DECLARATION

I declare that this thesis is my original work and has not been submitted elsewhere for an academic award. Where other people's work or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.

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ABSTRACT

The quality of drinking water is determined by measuring its physico-chemical, chemical, heavy metals and bacteriological characteristics. Quality drinking water is one which none of the above parameters can result to any significant health risk to its users upon consumption. A study was conducted to determine the sources and quality of drinking water in Isibania settlement, Nyamaharaga sub location of Kuria West Sub- County in Migori County. The following parameters were investigated; physico-chemical parameters comprising of pH, total dissolved solids, total alkalinity and total hardness, chemical; nitrate, nitrite, chloride, fluoride, sulphate, phosphate, sodium, magnesium, heavy metals; iron, manganese, cadmium, zinc, chromium, lead and bacteriological; total coliform and fecal coliform. Sixty closed ended questionnaires were administered to residents of Isibania who were selected through stratified random sampling to establish their demographic characteristics and sources of drinking water. A total of 27 samples were collected through stratified and purposive random sampling from water sources that included wells, streams and rainwater harvest. The questionnaires were analyzed using Statistical Package for Social Scientists while physico-chemical parameters were analyzed using portable electrochemical meters that had been standardized in the laboratory. Single Beam UV Spectrophotometric method was used for the analysis of nitrate, nitrite, phosphate, chloride, sulphate and fluoride. Flame Atomization Atomic Absorption Spectroscopic method was used to analyze for sodium and magnesium. Flameless Atomic Absorption Spectroscopic method was used to analyze for cadmium, zinc, chromium, lead, iron and manganese. Bacteriological quality was determined by measuring the most probable number of colonies for total coliform and fecal coliform after incubation. It was established that 98% of the respondents depended on wells, streams and rainwater harvest as sources of their drinking water. It was observed that; 14.8 % of the water samples had an average pH value of 5.3, 26% nitrites of 0.008 mg/L, 15% nitrates of 104.65 mg/L, 3% chromium of 0.08 mg/L, 7% manganese of 0.7 mg/L, 7% lead of 0.04 mg/L, 78% total coliform of 136 MPN and that 56% had fecal coliform of 120 MPN. It was further established that water from 82% of the sources studied was unsuitable for human consumption. This implies that majority of Kuria West residents consume poor quality water according to standards guidelines.

DEDICATION

I dedicate this work to my daughter Caren; who was born at the beginning of this study.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectroscopy
EDTA	Ethylenediamine tetra acetic acid
ISO	International Standards Organization
KS-EAS 12-2014	Kenya Standards- East Africa Standards
KEBS	Kenya Bureau of Standards
KNBS	Kenya National Bureau of Statistics
mg/L	Milligrams per Litre
MDG	Millennium Development Goals
MPN	Most Probable Number
Nm	Nanometer
NRC	National Research Council
pH	Potential Hydrogen
SDG	Sustainable Development Goal
SPSS	Statistical Package for Social Scientists
TDS	Total Dissolved Solids
UNEP	United Nations Environmental Program
UNESCO	United Nations Education, Scientific and Cultural Organization
UV	Ultra-Violet
WHO	World Health Organization
%	Percentage
µm	Micrometer

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Provision of adequate quality water is a fundamental right to citizens in most jurisdictions around the world; its availability continues to be threatened by population growth, climate change and industrialization. Studies by Appelo and Posma, (2005), indicate that citizens of developing countries use poor quality drinking water which is known to contribute to a number of health problems. This justifies for concerted efforts by all stakeholders to regularly and carefully assess its suitability for drinking purposes. Adediji and Ajibade, (2005), found that although drinking water may appear physically suitable for human consumption, it could still have properties which can significantly contribute to negative health effects to its consumers. These findings further dictated that quality assessment should involve measurement of physico-chemical, chemical, heavy metals and bacteriological parameters.

Drinking water sources are generally classified as either surface, groundwater or rainwater harvests; its quality is dependent on natural activities for instance: weathering, evapotranspiration, depositions, leaching, hydrological factors, biological processes and anthropogenic activities such as waste disposal, agriculture, industrialization and mining, (Appelo and Posma, 2005). According to De (1995), some water pollutants are persistent, may be dispersed over wide areas of aquifer with the extent of pollution depending on either or a combination of hydrological factors of the area, aquifer characteristics, nature of pollutants, soil physico-chemical properties in addition to the geological factors of the area.

Water quality is a measure of its condition relative to suitability for a particular purpose, (Alley, 2007). Based on quality assessment, drinking water can be classified as potable, palatable, contaminated or infected, (Chatterjee, 2001). The quality of drinking water is determined by comparing its physico- chemical, chemical, heavy metals and bacteriological properties that comprise of; total dissolved solids, potential hydrogen, total alkalinity, total hardness, nitrate, nitrite, phosphate, chloride, sulphate, fluoride, sodium, iron, manganese, magnesium, potassium, cadmium, zinc, chromium, lead, total coliform, fecal coliform with standards set by competent regulatory bodies such as the Kenya Bureau of Standards.

According to the World Health Organization (1997), quality water is one whose none of the above parameters can result in any significant health risk to its users upon longtime consumption and is therefore suitable both for human consumption and other applications. It further proposes that when a divergence is noted in the concentration of specific physico-chemical, chemical, oils and greases and bacteriological parameter, the cause and possible mitigation measures should be determined since consumption of such quality of water can cause significant human health impact depending on the concentration and period of consumption.

Pollution of a water source implies introduction of impurities resulting from either human or natural activities thereby creating an actual or potential danger to terrestrial and aquatic environments including humans when present at elevated levels. Water pollution is any change in the physico-chemical, chemical and bacteriological properties that make it unsuitable for consumption, (Government of Kenya, 2002). Pollution reduces water's socio-economic value and the general purpose for which it is expected to be used or make it harmful to life. This started with the agrarian revolution and was worsened by industrialization; significant pollutants derived from these related activities were imperceptibly into the hydrological environment. The presence of bacteriological properties such as coliforms on the other hand indicates a rapid movement of microorganisms from the surface to the water table.

Water quality standards are dependent on use and should be based on standard set out by governmental regulatory agencies. The criteria for assessment should be the degree of compliance to standards, especially when it is to be used directly from the source. Drinking water quality standards provide for the: physico- chemical, chemical and bacteriological characteristics of water that can be sustainably and safely consumed by humans throughout their lifetime. They are developed by standards organizations for example the guidelines for drinking water quality by World Health Organization (1993), covers about sixty quality parameters. These standards have been domesticated by different jurisdictions appropriately in setting up regulations and legislations on drinking water quality parameters. Drinking water treatments depend on the potential of particular methods of reducing the pollutants to levels set by standards regulatory bodies. The treatment may vary from simple to an intensive complex physico-chemical and disinfection. Many jurisdictions have enforcement mechanisms for ensuring that after treatment, water would be useful for human consumption.

1.2 Statement of the Problem

The United Nations member states adopted the Millennium Development Goals (MDG) as a global development agenda where it envisioned having a majority of the world's population accessing quality drinking water by the year 2015. Member states strived to attain this target but for the African States this goal was unfortunately not realized, (Government of Kenya, 2006). The current global development agenda, the Sustainable Development Goals (SDG), envisions achieving safe and affordable drinking water by the year 2030. Provision of adequate quality water has remained a challenge for developing countries. Approximately 187 million people depend on groundwater for domestic purposes with an estimated 783 million people not accessing adequate quality water, (World Health Organization, 2012).

The Constitution of Kenya, (Government of Kenya, 2010), obligates the government to put in place mechanisms for provision of adequate quality water and basic sanitation to all citizens. It also provides for litigations against the government for non- compliance. The implementation of the Kenya national water policy prioritized groundwater quality management. It envisioned: sustainable use of water resources, safe waste disposal and environmental protection, establishment of institutions for the achievement of sectorial development and management. The policy also prioritized the development of sustainable systems for efficient water resources management, distribution and sanitation development, (Government of Kenya, 1999).

Isibania urban center covers an area of 5.8 square kilometers with a population of 23,556 and 6473 households spread in twelve estates. It is one of the fastest commercial growing centers of Kuria West Sub-County. The residents of Isibania have limited access to quality drinking. Sanitation is by pit latrines and owing to their proximity drinking water sources, the possibility contaminated cannot be ruled out. The residents are in doubt of the quality of drinking water from these sources leading to their evasion. Furthermore, information on the quality of water from the available sources and the health implications on the residents on their continued consumption were scanty. It was against this background that this study sought to determine the sources and to assess the quality of drinking water from selected sources in Isibania urban centre. The study sought to answer the following research questions;

1. What are the sources of drinking water for the residents of Kuria West?
2. What are the physico-chemical characteristics; potential hydrogen, total dissolved solids, total hardness, total alkalinity of drinking water from the selected sources?
3. What is the chemical characteristics; nitrate, nitrite, phosphate, chloride, sulphate, fluoride, sodium, magnesium, of drinking water from the selected sources?
4. What is the heavy metal characteristics; iron, manganese, cadmium, zinc, chromium, of drinking water from the selected sources?
5. What is the bacteriological characteristic; total coliform, fecal coliform of drinking water from the selected sources?

1.3 Objectives of the Study

The overall objective of this study was to assess the drinking water quality from selected sources in Kuria West of Migori County.

The specific objectives were:

1. To determine the sources of drinking water for the residents of Kuria West.
2. To determine the physico-chemical parameters; potential hydrogen, total dissolved solids, total hardness, total alkalinity of drinking water from the selected sources.
3. To determine the chemical parameters; nitrate, nitrite, phosphate, chloride, sulphate, fluoride, sodium, magnesium in drinking water from the selected sources.
4. To determine the heavy metal parameter; iron, manganese, cadmium, zinc, chromium in drinking water from the selected sources.
5. To determine the bacteriological parameters; total coliform, fecal coliform in drinking water from the selected sources.

1.4 Justification and Significance of the Study

Drinking water quality assessment forms the basis of making strategic decisions on sustainable treatment methods, long term environmental impact and on the general use of these resources. This study was necessitated by the fact that the residents of Kuria West in Migori County had limited access to adequate quality drinking water. Due to rapid increase in human population and industrialization the quality of drinking water from traditional sources may be compromised to the extent of causing serious public health concerns.

Isibania in particular is affected most since it is a mixture of urban and rural settlements with relatively low distribution of drinking water sources. The knowledge obtained from this study will be useful to the Government in executing its constitutional mandate of providing adequate quality drinking water and sanitation to the residents of Kuria West. The knowledge will also be useful to other stakeholders with interests in provision of water to the residents of Kuria West and other areas within the County.

1.5 Scope and Limitations of the Study

The study was limited to assessing the drinking water quality for the residents of Isibania which is administratively found in Nyamaharaga Sub Location, Bukira West Location of Isibania Division in Kuria West Sub County within Migori County. The study focused on determining the physico-chemical parameters; total dissolved solids, potential hydrogen, total hardness, total alkalinity, chemical parameters; nitrite, nitrates, phosphate, chloride, sulphate, fluoride, sodium, magnesium; heavy metals; iron, manganese, cadmium, zinc, chromium, lead and bacteriological parameters; total coliform, fecal coliform in water from selected drinking water sources. The study was also limited to determining the sources of drinking water for the residents of Kuria West.

The study expected to encounter a number of limitations during sampling including being viewed with suspicion by the residents and in particular most of the respondents. These were overcome by site reconnaissance, assurance of confidentiality, authorization from local administration and invitation of drinking water sources’ owners to witness sampling.

CHAPTER TWO: LITERATURE REVIEW

2.1 Drinking Water Sources

Globally 70% of the earth's surface is covered with water but its stress continues to be a great concern since 97% occurs as saline water masses, 2.5% is freshwater trapped as ice and glaciers and only 0.5% that is in aquifers, lakes, reservoirs, rivers, streams, and rainfall is readily available for human use, (Oki & Kanae, 2006). Precipitation which is dependent on seasons, weather patterns and climate change is a major source of quality drinking around the world. Sources of drinking water continue to be polluted as a result of human activities such as manufacturing, agriculture, or individual misuse. Chemical pollution of water sources results from leakages of waste disposals, industrial discharges, leaching, spills, and improper disposal household wastes, (Hutton and Chase, 2016).

2.1.1 Wells

A well is considered as a water resource created through excavation in the ground aquifers which varies in terms of: depth, geological factors, water quantity and quality. Depending on the nature and available resources, drawing of water from a well is either mechanized or mechanical. Studies by Adediji and Ajibade (2005), shows that there is a correlation between the quality of groundwater and the presence of nearby dumpsites. The same studies found that during the dry season, extensive withdrawal of groundwater lowers the water table and also changes its: physico-chemical, chemical and bacteriological characteristics.

Groundwater sources such as wells provide two third of drinking water worldwide and has been exploited since the era of industrial revolution. New methods of bringing this water to the surface are developed and improved consistently ever since (Freeze and Cherry, 1979). It is a geological unit with water in sufficient quantities to allow economic development; distribution controlled by lithology, stratigraphy and structural features. Wells have been identified as major sources of drinking water; population growth has led to increased requirements. Its fitness for human consumption is dependent on it's: location, aquifer properties and accessibility. According to Ballukraya and Ravi, (1999), two billion people who depend on wells for drinking water have been affected significantly; unsustainable high demand and pollution resulting from natural activities, human activities and climate change.

Wells water quality assessment involves tracing and identifying the sources of pollution which could pose a potential contamination threat to it. A study by Hrudey and Hrudey, (2004) cited that groundwater quality is dependent on its; physico-chemical, chemical and bacteriological properties. Pure water is colorless, odorless and tasteless, these are indicators of its: physico-chemical and general chemical characteristics. Any sudden change in these parameters is not consistent with a stable water source, (Appelo and Posma, 2005). Wells water contains mineral ions that are dissolved from the geological environment and dissolved solids which are mainly the organic and inorganic constituents. The physico-chemical, chemical, heavy metals and bacteriological characteristics of well water are dependent on: mass transport, chemical compositions and reactions, precipitation, and human activities such as agriculture and industrialization.

2.1.2 Streams

A stream as an example of surface water sources is described as water on the surface of the earth which has been found to constitute 80% of global drinking water sources, (Davis & Masten, 2004). Streams are prone to environmental contamination from human activities such as: agricultural, industrial and domestic. These activities may introduce many types of water pollutants like: organic materials, heavy metals, pesticides, fertilizers and hazardous chemicals. Naturally stream water quality has been found to be dependent on: atmospheric inputs, weathering of bedrock and climatic conditions, (Gibbs, 1970).

2.1.3 Rainwater Harvest

Rainwater harvest involves storage of rainwater collected from rooftops; has remained a major source of drinking water for both rural and urban settlements more so in areas with reliable rainfall patterns. It includes the: diversion, collecting, storage and management of runoffs thereby providing relatively safe and clean water. Rainwater quality is dependent on the extent of anthropogenic contamination and the type of storage. Its harvest has been cited as instrumental in reducing pressure on surface and groundwater thereby contributing to the replenishment of other water sources and soil conservation (Malesu *et al.* 2007). Although rainwater is a free occurring natural resource; its development has been impeded by initial cost related to: collection surface, guttering and storage.

2.2 Water Quality

2.2.1 Potential Hydrogen

Potential hydrogen (pH) is the negative logarithm of the hydrogen ions concentration which gives an indication of the acidity or alkalinity of water. Acidic water contains extra hydrogen ions; one that is basic contains extra hydroxyl ions while pure water is neutral at 25°C. Normal rainwater is acidic owing to atmospheric gases and safe for drinking with pH value in the range 5.5- 9.5, (Alley, 2007). The pH value of natural groundwater sources generally ranges from 6 to 9 and varies depending on the geological nature of the parent rock, mineral deposits, wastewater discharges and on aquatic biochemical activities especially decomposition and respiration. It is one of the parameters that are suggestive of the level of contamination of water and is manifested on taste, odor and appearance; too acidity or alkalinity makes water unpalatable for drinking and has a bearing in determining consumer perception and behavior towards the water.

2.2.2 Total Dissolved Solids

Total dissolved solids are expressions of the summation of all dissolved solids of organic and inorganic materials in water. It is a physico-chemical parameter that affects other water characteristics such as: electrical conductivity, taste and hardness. It has been reported that the desirable levels of total dissolved solids for drinking water should be values not exceeding 500 mg/, though with exceptions values of up to 1500 mg/L is allowed, (Khan and Khan, 1985). Total dissolved solids can be determined at the sampling sites using a standardized portable electrochemical meter and is reported in milligrams per litre, (mg/L).

2.2.3 Total Alkalinity

Alkalinity is an expression of the ability of water to neutralize of acids or its resistance to pH variations. Determination of alkalinity of water helps to estimate the amount of lime that could be needed for given water softening; it is useful in applications such as controlling corrosion in boilers, (Alley, 2007). Groundwater alkalinity is generally attributed to the presence of bicarbonates that are formed as a result of chemical reactions taking place in the soils through which the water percolates. Poorly buffered water for example will have a relatively low alkalinity that will be prone to pH reduction. Alkalinity limit for drinking water quality consideration for surface water is 400 mg/L.

2.2.4 Total Hardness

Total hardness of water is a characteristic that represents the summation of calcium and magnesium ions expressed as their equivalent carbonates. It may be caused by natural geological processes or pollution resulting from anthropogenic activities and may be seen in the formation of scum when soap is used in water. Hardness causes depositions in water storage and distribution networks and is expressed in mg/L. According to Heath (1983), water with total hardness values: less than 61 mg/L is soft, 61- 120 mg/L, is moderately hard, 121-180 mg/L is hard and above 180 mg/L is very hard. Hard water causes reduction in its flow due to clogging of pipes; this increase heating costs and introduces unpleasant taste. Soft water on the other hand has been found to have corrosive effect on metal plumbing due to high levels dissolved oxygen.

2.2.5 Nitrate

Nitrogen occurs in water as: organic, ammonia, nitrite and nitrate. In sewage, nitrogen is found in the form ammonia which converted to nitrites and nitrates upon microbes' activities. Nitrate is a nutrient for the growth of plants and is known to cause eutrophication, giving water unpleasant odor as well as reducing its clarity as a result of growth of the algae which degrades the water quality. Nitrate is the oxidized and stable form of nitrogen in water; its sources are anthropogenic activities such as: agriculture, emissions, sewage contaminations, waste disposals, and decomposition of biological materials, (American Public Health Association, 2005).

The concentration of nitrate ions in freshwater is less than 3 mg/L; consumption of drinking water with nitrate ions concentration above 10 mg/L is a potential risk of a Blue baby Syndrome; a fatal disease characterized by conversion of hemoglobin by nitrates into a form that is less inefficient or completely incapable of oxygen transportation in the body system, (Chapman *et al*, 1992).

Nitrate ions in a water sample can be determined by spectrophotometric method through reaction with NitraVer5 reagent. The cadmium metal in the reagent reduces nitrates in the sample to nitrites. The nitrite ions reacts in an acidic media with sulpfanilic acid to form an intermediate diazonium salt. The salt couples with gentisic acid to form an amber colored solution, tests rest are obtained in mg/L at 500 nm, (Hach, 2005).

2.2.6 Nitrite

Nitrite is an intermediate compound formed during the oxidative reaction of ammonia to form nitrate through the microbes' facilitated nitrification and denitrification of organic nitrogen compounds. Discharge of effluents into water sources leads to increase in nitrite concentrations whose presences is an indication of pollution. This form of nitrogen is a plant nutrient that encourages eutrophication and is harmful to the aquatic abiotic factors. In natural water nitrite concentrations are generally lower than 0.01 mg/L. Consumption of water with levels exceeding 1.0 mg/L is harmful to humans; has been associated with health complications such as methemoglobinemia which causes cyanosis and asphyxia depending on levels of exposure, (Chapman *et al*, 1992),

The concentration of nitrite ions in a water sample can be measured spectrophometrically when it is treated with NitraVer3 reagent. The nitrite ions in the sample reacts with sulpfanilic acid from NitraVer3 reagent to form an intermediate diazonium salt. This couple with chromotropic acid to produce a pink coloured complex directly proportional to the amount of nitrite present, the concentration in mg/L is obtained at 507 nm, (Hach 2005).

2.2.7 Phosphate

Phosphates widely used as a component of a wide range of agrochemicals and detergents; occurs in living organisms and in biological wastes. Agricultural, industrial and domestic waste discharges are contributors of phosphates to water sources which occurs both in inorganic and organic forms. Though there is no World Health Organization's (WHO) guidelines for the concentration for phosphates ions in drinking water, studies indicate that concentrations should not exceed 0.02 mg/L, (World Health Organization, 1993). Phosphates are responsible for eutrophication which impact negatively on drinking water quality of water in addition to interfering with water treatment. Phosphates are known to adhere to the soil, making their extraction slow, thus the difficulty of reversing the effects of eutrophication once it has started, (United Nations Environmental Program, 2006).

The concentration of phosphate ions in water can be measured spectrophometrically when the sample is treated with molybdovanadate reagent. The phosphate ions in the sample react with molybdate in an acidic medium to produce a complex of phosphate/molybdate complex. In the presence of vanadium, yellow molybdovanadophosphoric acid is formed; the intensity of the yellow color is proportional to the phosphate concentration which is measured in mg/L at 430 nm, (Hatch, 2005).

2.2.8 Chloride

Chloride ions' concentrations in groundwater are dependent on both natural and anthropogenic activities such as disposals of: agrochemicals, domestic and industrial wastes, (Zoeteman, 1980). Although its detectable limit in water is dependent on the cations of its associated salts, concentrations above 250 mg/L makes drinking water to have unpleasant taste. It reacts with metallic pipes to form corresponding soluble salts thereby increasing the concentration of metals in water and increasing corrosion of the pipes, (Weast, 1986). Other than in cases of impaired sodium chloride metabolism, little information is available on its toxicity in humans, (International Standards Organization, 1989).

The concentration of chloride ions in a water sample is measured spectrophotometrically when treated with mercuric thiocyanate. Chloride ions in the sample react with the mercuric thiocyanate to form mercuric chloride and liberate thiocyanate ions. Thiocyanate ions react with the ferric ions to form an orange ferric thiocyanate complex. The amount of this complex is proportional to the chloride concentration and is measure in mg/L at 455 nm, (Hach, 2005).

2.2.9 Sulphate

Sulphates occur in all natural groundwater from sources such as volcanic activities, weathering, decomposition and combustion; levels varying depending on the geological nature of the aquifer, (Davies, 2007). Sulphates are derived from its compounds of heavy metals which are then leached into ground and surface water sources. Another source of sulphates into the aquatic environments is through disposal of domestic and industrial wastes especially from the mining industry. The fate of dissolved sulphates in water includes reduction to sulphides, volatilization as hydrogen sulphides, precipitation as insoluble salt and incorporation into the biomass.

High levels of sulphate have a purgative effect in water and in amalgamation with other ions cause the water to have a characteristic bitter taste. A Study on underground water quality by Curtis (1989) indicates that high levels of sulphates favors increase in phosphates levels and eutrophication in water thus affecting the aquatic ecosystems. The same study has shown that sulphates levels in natural waters varies between 2 mg/L to 80 mg/L; although in areas with sulphates minerals or susceptible waste disposal, concentrations higher than 1,000 mg/L may be observed.

Sulphate ions levels in a water sample are determined when it is treated with SulfaVer4 reagent. Sulphate ions in the sample react with barium in the SulfaVer4 and form a precipitate of barium sulphate. The amount of turbidity formed is proportional to the sulphate concentration and is measured in mg/L at 450 nm, (Hach, 2005).

2.2.10 Fluoride

Fluoride is naturally present in both groundwater and surface water at varying concentrations of up to 100 mg/L, (Ayoob & Gupta, 2006). Consumption of water with fluoride concentrations higher than 1.5 mg/L has been established to be toxic to animals including human. Health challenges associated with chronic consumption of water with fluoride concentrations beyond optimum level include: colouring of teeth, dental and skeletal fluorosis (World Health Organization, 2004). Fluoride in drinking water within the optimum concentration helps in preventing dental decay.

The concentration of fluoride ions in water is determined spectrophometrically when it is treated with spadns reagent. Fluoride ions in the sample react with a red zirconium- dye solution and combines with part of the zirconium to form a colorless complex. The extent of bleaching of the red color is proportional to the fluoride concentration and is measured in mg/L at 580 nm, (Hach, 2005).

2.2.11 Sodium

The source of sodium in natural water is its salts and mineral deposits. In regions with sodium mineral deposits, groundwater generally contains higher concentrations than surface waters, (World Health Organization, 1979). For natural portable water, the concentration of sodium ions is 200 mg/L at maximum. Anthropogenic capable of contributing its significant quantities to natural water include domestic and industrial waste discharges and agrochemicals which can increase the concentrations up to 300 mg/L, (World Health Organization, 1979). Sodium compounds used for drinking water treatment for example those for pH adjustment can result to its ions concentrations raising to 570 mg/L while domestic softeners are capable of increasing it to 300 mg/L, (National Academy of Science, 1977).

2.2.12 Magnesium

Sources of magnesium in drinking water includes: decomposition of magnesium aluminosilicates and from dissolution of magnesium limestone, magnesite, gypsum and other minerals. Anthropogenic contamination of drinking water sources with magnesium is not common. Magnesium plays an important role as a cofactor and activator of more than 300 enzymatic reactions including: glycolysis, adenosine triphosphate metabolism, transport of sodium, potassium and calcium through biological membranes, synthesis of proteins and nucleic acids, neuromuscular excitability and muscle contraction.

The drinking water quality for magnesium ions is 100 mg/. Though there is little evidence of magnesium poisoning; long term consumption of its supplements and medicines has been known to cause: muscular feebleness, fatigue and mental disorders. Magnesium deficiency increases risk to humans of developing various pathological conditions such as vasoconstrictions, hypertension, cardiac arrhythmia, atherosclerotic vascular disease, acute myocardial, diabetes and osteoporosis, (Lenntech, 2009). In plants, magnesium is constituent of chlorophyll and therefore plays a role in the process of photosynthesis.

2.2.13 Iron

Iron is an abundant earth metal that occurs either as sulphates, oxides, hydroxides or carbonates. Its aeration in the soil has been attributed to generally causing changes on the quality of water as it percolates through its compounds. These quality changes are dependent on the: water table, leaching, oxidation and pH value, (National Research Council, 1979). Iron's presence in groundwater is from mineral sources; its concentration in water is influenced by chemical reactions taking place on the parent rock and to anthropogenic activities, (Drever, 1988). Iron has been attributed to the promotion of undesirable bacterial growth within water sources and supply structures by causing depositions on the piping systems, (International Standard Organization, 1988).

Iron is an essential trace element in living organisms; in human its largest part is presented as hemoglobin, myoglobin, and haem-containing enzymes with other major fraction being stored in the body as ferritin and hemosiderin mainly in the spleen, liver, bone marrow and in the striated muscle. The quality standard limit of iron ions in drinking water is 0.3 mg/L; chronic iron overload is caused by a genetic disorder characterized by increased iron absorption from diet and diseases that require frequent blood transfusions, (Bothwell, 1979).

2.2.14 Manganese

Manganese's water characteristic is similar to iron though its concentration in unpolluted waters is usually less than half the concentration of iron, (Davis and De, 1970). It has a low permissible concentration because it causes unpleasant taste in water. Oxides of manganese are common in swampy areas and are known to accumulate in aquatic environments; sources of manganese ions in drinking water have been associated with waste disposals of industrial and agrochemicals, (Adama, *et al.*, 2014).

Human consumption of water with manganese ions concentration beyond 0.1 mg/L is known to have health effects such as: liver damage, neurotoxicity, chronic respiratory inflammation and birth defects, heart defects, imperforate anus and deafness, in addition to aggressive behavior and disturbances in libido, (Enuneka *et al*., 2013).

2.2.15 Cadmium

Cadmium is a poisonous heavy metal whose acute exposure to human leads to health challenges such as fever and muscle ache. Extreme exposures to cadmium causes: acute respiratory, circulatory, kidney and liver disorders, (Elkins and Pagnotto, 1980). Sources of cadmium in drinking water are mainly from industrial waste disposal. The World Health

Organization has recommended a concentration of 0.005 mg/L of cadmium ions in drinking water as the acceptable limit.

2.2.16 Zinc

Zinc is an essential trace mineral in the bodies of humans with at least forty different enzymes requiring it as a cofactor. The sources of zinc in water are through disintegration and decay of natural deposits of its compounds and waste disposals (Job, 2009). In natural water the concentrations are up to 40 mg/L, though for drinking water there is an aesthetic limit of 5 mg/L. Water containing more than 5 mg/L has a chalky appearance and metallic or astringent taste, (Elinder *et al* (1986). According to Nriagu (1980), zinc concentrations above the normal range has been found in regions prone to leaching of its compounds.

Zinc is an antidote for cadmium toxicity in humans whose requirement ranges from 15 to 20 mg per day. Health challenges such as growth, reproduction, immune and appetite disorders have been attributed to zinc deficiencies (World Health Organization, 2008). Studies have shown that deficiencies of zinc seem to grossly affect pregnant women with possible remedy being suggested as taking zinc supplements at a rate of 25 to 30 mg per day, (Osendarp, *et al.*, 2001).

2.2.17 Chromium

Sources of chromium into water bodies includes natural processes acting on chromium compounds and disposal of its compounds from anthropogenic activities, (Cheryl and Susan, 2000). Chromium compounds are persistent in water; has tendency of accumulating in the hydrological environment and being moved over a wide geographical area. Chronic consumption of water with chromium concentrations above 0.08 mg/L has been known to cause health complications such as respiratory, birth and fertility disorders. Other effects include formation of tumors, cancer and skin rashes, (Khopkar, 2006).

2.2.18 Lead

Lead is a highly poisonous heavy metal with carcinogenic properties. It occurs naturally in groundwater as a result of geologic processes on its deposits. Other sources of lead in the environment include waste disposal and corrosion of its compounds; it is commonly found in the air, soil and in water. Chronic consumption of drinking water with lead concentrations above 0.001 mg/L is injurious to human as it affects the nervous system, kidney, liver and blood vessels. Early symptoms of poisoning includes: abdominal pain, depression, loss of appetite, nausea, constipation, and muscle pain, fatigue, decreased libido, problems with sleep, anemia and excretion of hemoglobin in urine, (Jagadish, 2010).

Studies have shown that short-term exposure to extreme levels of lead in drinking water causes death through complications such as convulsion, vomiting, diarrhea or coma, (Merrill *et al.*, 2007). Other studies have also shown that lead depresses sperm count and contributes to neurological problems, especially in children with chronic lead exposure, (World Health Organization, 2004).

2.2.19 Total Coliforms and Fecal Coliforms

The presence of biotic factors such as plants, fungi and bacteria in a water resource has been found to be a useful indicator of the water quality; some microorganisms can give an indication on the level of pollution (Abbas *et al.*, 2014). Studies indicate that of waterborne diseases such as typhoid, leptospirosis, tularemia, shigellosis, cholera among other are caused by bacteria and outbreaks of these diseases have been associated with lack of good sanitary practices, (Tchobanoglous *et al.*, 1985). The existence of bacteria in water indicates that it has been polluted and that it presents a health risk to its user. Introduction of bacteria into water is a resultant of both natural and anthropogenic activities. Human faeces for example may contain pathogenic microbes which are bacterial, viral or parasitic. Though some types of bacteria found in groundwater are harmless, ingestion of pathogenic organisms could cause health challenges to its consumers. Further the presence of microbes in water affects its palatability for drinking purposes, (Nathanson, 2004).

In the recent past, the importance for detection of bacteriological contaminants in drinking water sources has been occasioned by increase in sewage areas and bacteriological discharges. Irrespective of the advanced methods of wastewater treatment and disposal, human faeces are principal sources of bacteriological contaminants. The objective of bacteriological water treatment is to ensure its suitability for drinking purposes. The principal source of disease causing agents in water is biological wastes mainly emanating from improper disposal, adsorptions and runoffs. Other sources include leaching of biological materials into groundwater sources with the risks of contamination being elevated by their poor construction or maintenance.

Coliform is a class of bacteria that survive in the water longer than most pathogens, (Tomar, 1999). Total coliforms is the summation of microbes found in the environment; living in soils, plants and in intestines of animals. Although some coliforms are not harmful, their presence in water indicates that the source is vulnerable to contamination by harmful microbes and requires urgent professional attention. Determination of the entire spectra of pathogens is not only expensive but also complicated; measurement of this parameter is used as measure the extent of pollution and sanitary quality of water. Sewage contaminated water will always contain coliform, (Nathanson, 2004).

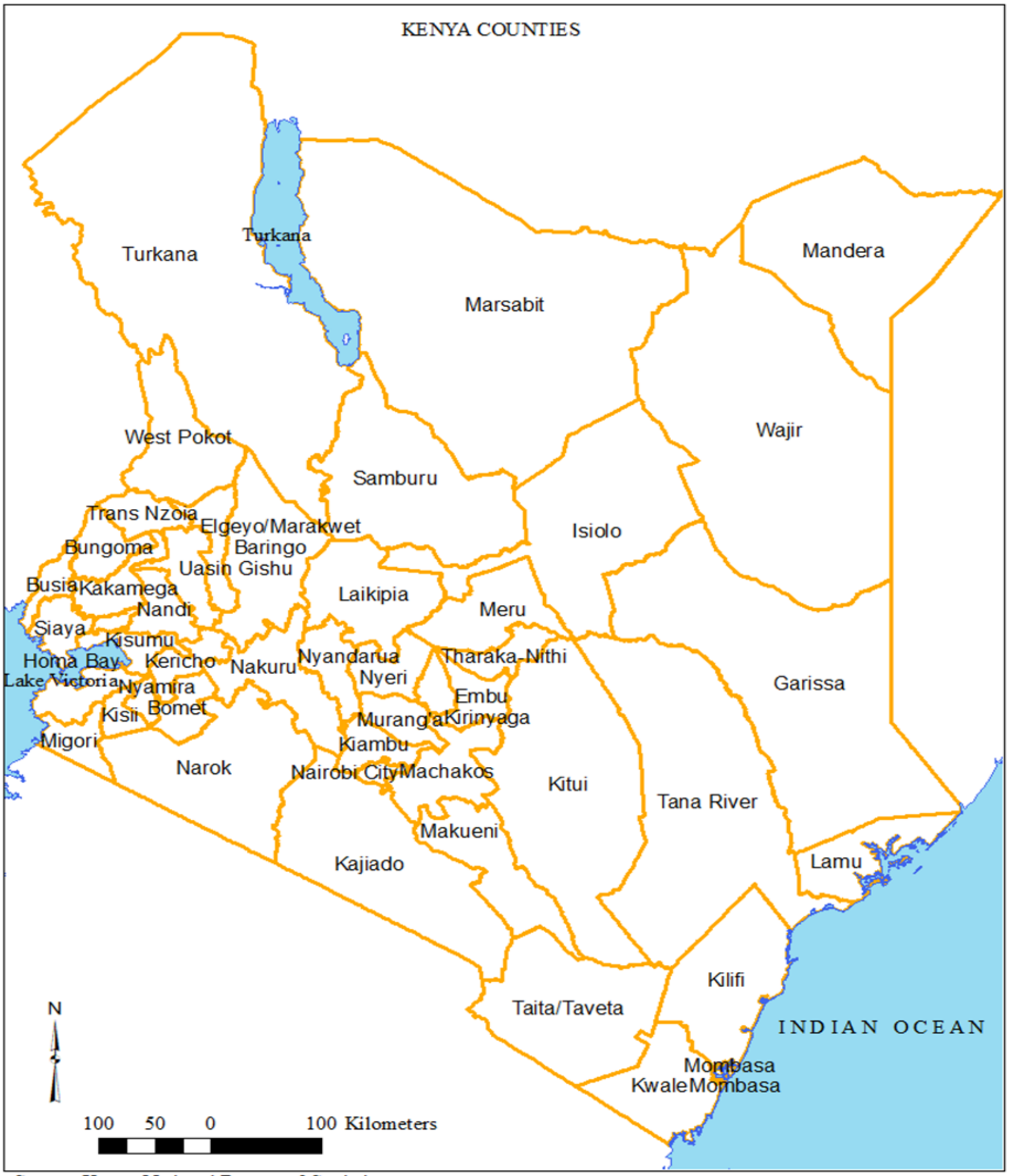
Fecal coliform is a class is of bacteria that occur only in wastes of warm-blooded animals. Unlike other members of the total coliform they can breed at extreme temperatures. Their presence in water is an indication of a recent fecal contamination and risk of microbe pathogens, (Nathanson, 2004). In order to do bacteriological drinking water quality assessment, it is good practice to determine suggestive organisms which are easy to detect and identity, and are of similar origin as the pathogens, these organisms should be of the same or advanced survival characteristics than the pathogens and must not be pathogenic.

CHAPTER THREE: MATERIALS AND METHODOLOGY

3.1 Area of the Study

The study area, Isibania urban center is in Nyamaharaga Sub Location, Bukira West Location in Isibania Division within Kuria West Sub County of Migori County. The area lies on the Latitude 1˚14`21.9`` South and Longitude 34˚28`45.2`` East and is approximately 22 kilometers from Migori town along the Isibania-Migori Road that leads to the United Republic of Tanzania. Isibania is a cosmopolitan and covers 5.8 square kilometers with a population of 23,559 in 6473 households spread in twelve estates namely Nyamonge, Nyaichoha, Chamberi, Maroa Gitwi, Border Point, Kihutwa, Nairobi Ndogo, Highway, Gati Kimwamu, Nyabikaye, Bukumburi and Nyamwinyi, (Kenya National Bureau of Statistics, 2019).

While Nyamonge, Nyaichoha, Chamberi, Maroa Gitwi, Border Point, Kihutwa, Nairobi Ndogo, and Highway estates are densely populated and well developed with commercial entities. Nyabikaye, Bukumburi, Gati Kimwamu and Nyamwinyi on the other hand are sparsely populated and are mainly farmlands. Economic activities includes: motor vehicle repair and auxiliary services, housing constructions, wholesale and retail markets, road transport, petroleum industries, metalwork, hospitality industries and agricultural activities.

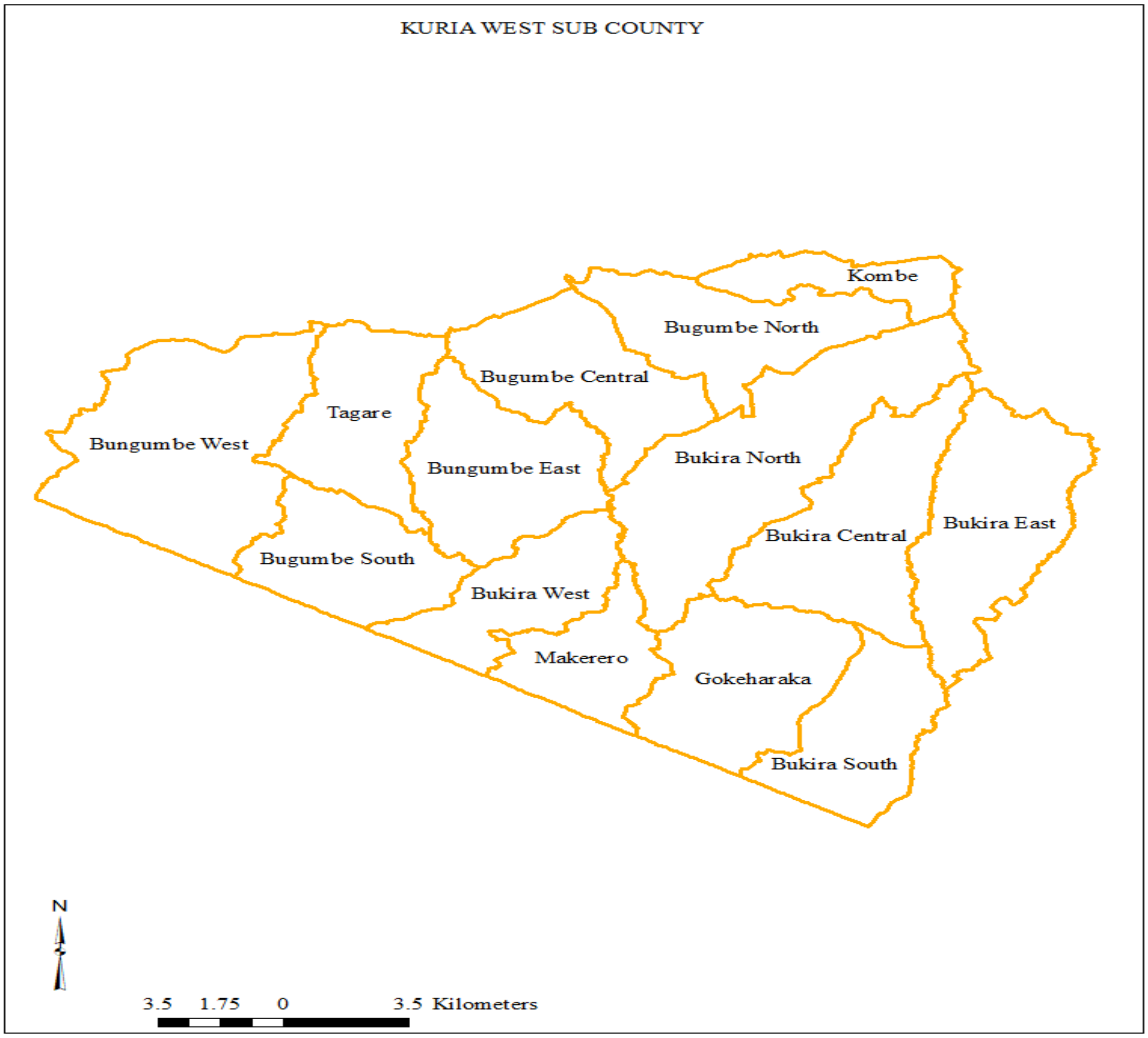


Source :Kenya National Bureau of Statistics

Figure 3.1(a): Map of Kenya Showing Counties

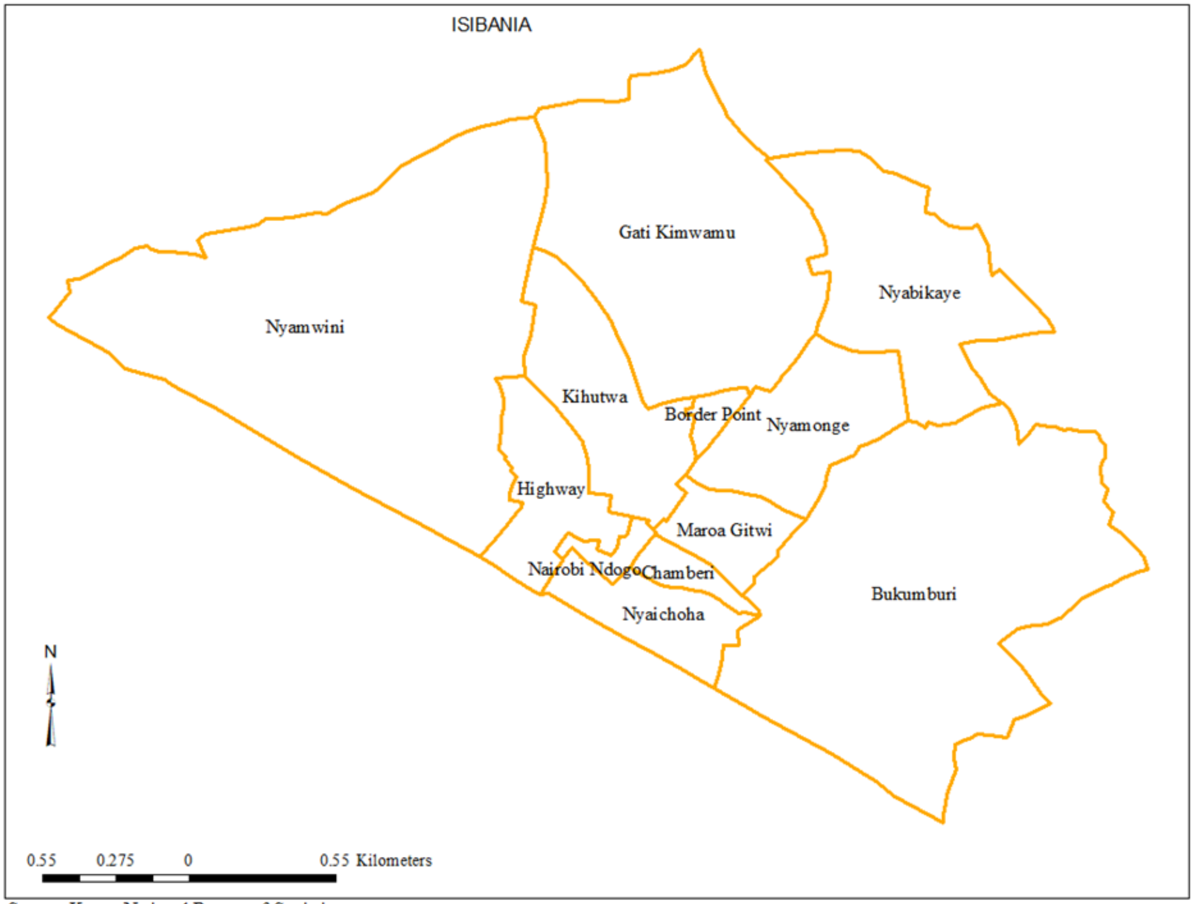
Source :Kenya National Bureau of Statistics

Figure 3.1(b): Map of Migori County Showing Sub Counties



Source :Kenya National Bureau of Statistics

Figure 3.1(c): Map of Kuria West Sub County Showing Locations



Source :Kenya National Bureau of Statistics

Figure 3.1(e): Map of Isibania Showing Estates

3. 2 Sample Design

Water samples were sampled through stratified random sampling from a total of twenty four selected drinking water sources. A well and a rainwater harvest was systematically selected from Nyamonge, Nyaichoha, Chamberi, Maroa Gitwi, Border Point, Kihutwa, Nairobi Ndogo, Highway, Gati Kimwamu, Nyabikaye, Bukumburi and Nyamwinyi estates. In addition the three natural streams located in Bukumburi, Gati Kimwamu and Nyabikaye estates respectively were also selected.

3.3 Research Design

Primary data was obtained from questionnaires that were administered to heads of households who were selected randomly from each of the estates. Secondary data was sourced from official government documents and publications.

3.4 Reagents, Instruments and Apparatus

3.4.1 Reagents

The following reagents were used: total hardness indicator, kovacs reagent, borax, sodium hydroxide, sodium sulphate, ethylenediamine tetra acetic acid salt, magnesium chloride, calcium chloride, sodium chloride, calcium carbonate, standard pH buffers, standard total dissolved solids solution, concentrated nitric acid and ferric iron solution; all were analytical grades sourced from Kobian Scientific Limited. NitraVer5, NitraVer3, SulfaVer4, molybdovanadate and spadns reagents and mercuric thiocyanate solution were sourced from Permachem Reagents Limited; a subsidiary company of Hach. Grade1 purified water was prepared through purification.

3.4.2 Instruments

The instruments used in the study were as tabulated in table 3.4.2

S/No.	**Equipment**	**Model**	**Manufacturer**
1.	Atomic Absorbance Spectrophotometer	ContrAA	Analytikjena.
2.	Ultra Violet Spectrophotometer	DR5000	Hach Company
3.	pH Meter	PC700	Eutech Instruments
4.	Total Dissolved Solid Meter	PC700	Eutech Instruments
5.	Total Alkalinity Meter	PC700	Eutech Instruments
6.	Puranity Ultra-Pure Water System	TU12UV/UF	VWR-UK

Table 3.4.2: Table showing model and manufacturers of instruments

3.4.3 Apparatus

The following apparatus were used: conical and volumetric flasks, Durham tubes, Marctney bottles, porcelain beakers, filter cartilages.

3.5 Cleaning and Sterilization of Glassware

All glassware for sampling and laboratory analysis were thoroughly cleaned and later soaked for 24 hours in 50% nitric acid. They were then rinsed soaked in grade1 purified water for 6 hours to leach off any adsorbed nitric acid and were finally dried in open racks. Glassware for sampling water for bacteriological determination was additionally sterilized by autoclaving.

3.6 Sampling and Sample Storage

From each of the selected sources in all estates, 2 litres of water sample was collected in a glass bottle. For bacteriological parameters determination, 0.15 litres of water sample was collected from each of the selected sources using sterilized 0.2 litres glass bottles and kept in a cooler box. Each of the water samples was labeled, coded and delivered within 12 hour to the Government Chemist Department's Laboratories in Nairobi for analysis.

3.7 Preparation of Working Solutions

3.7.1 Grade 1 Purified Water

Prepared using Puranity Ultra-Pure Water System; tap water was passed through 5 and 1 microns filters to remove sediments and other small particles. It then went through cationic and anionic cartilage filters to remove all the ions.

3.7.2 Total Hardness Buffer

In 0.8 litres of grade1 purified water, 40 grams of borax was dissolved. In 0.1 litres of grade1 purified water, 10 grams of sodium hydroxide and 5 grams of sodium sulphate were dissolved. The two solutions were then mixed in a 1 litre volumetric flask and topped to the mark with grade1 purified water.

3.7.3 1 Normal Sodium Hydroxide

In 1 litre of grade1 purified water, 40 grams of sodium hydroxide was added and allowed to completely dissolve.

3.7.4 Ethylenediamine Tetraacetic Acid Standard

In 0.8 litres of grade1 purified water, 4 grams of ethylenediamine tetra acetic acid salt was dissolved, 0.0215 litres of 1 normal sodium hydroxide and 0.1 grams of magnesium chloride were then added. This solution was then titrated with standard calcium chloride solution and adjusted to ensure that 0.001 litres of Ethylenediamine tetra acetic acid contained 1 milligrams of calcium carbonate.

3.7.5 MacConkey Broth

In 1 litre of grade1 purified water, 40 grams of MacConkey was dissolved.

3.7.6 Bacteriological Peptone

In 1 litre of grade1 purified water, 10 grams of peptone and 5 grams of sodium chloride were dissolved.

3.8 Determination of Drinking Water Sources

An open ended questionnaire was administered to five randomly selected heads of households from each of the estates. The questionnaire sought to determine the demography; gender, age bracket, educational level, sizes of households and length of stay in Isibania. Additionally information about drinking water sources and households' daily drinking water requirements was sought through the questionnaire.

3.9 Determination of Physico-chemical Water Quality

3.9.1 pH

The pH meter was calibrated with a standard buffer. Into a 0.2 litre beaker, 0.15 litres of the water sample was taken and a pH meter electrode immersed. The pH values were recorded from the device. The measurements were taken in triplicate from which the average value obtained was taken as pH of the water sample.

3.9.2 Total Dissolved Solids

The total dissolved solids meter was calibrated with a standard solution. Into a 0.2 litre beaker, 0.15 litres of the water sample was taken and a total dissolved solids meter electrode immersed into the sample. The total dissolved solids values were recorded from the device. The measurements were taken in triplicate from which the average value obtained was taken to be the TDS of the water sample.

3.9.3 Total Alkalinity

The Total alkalinity meter was calibrated with a standard solution. Into a 0.2 litre beaker, 0.15 litres of each of the water sample was taken and a total alkalinity meter electrode immersed into the sample. The total alkalinity values were was recorded from the device. The measurements were taken in triplicate from which the average value obtained was taken to be the total alkalinity of the water sample.

3.9.4 Total Hardness

Into porcelain beaker, 0.025 litres of the sample was taken, the one tablet of total hardness indicator was added followed by 0.001 litres of the buffer. The sample was then titrated with total hardness ethylenediamine tetra acetic acid (EDTA) standard. Total hardness was then calculated in mg/L as:

$$\text{Total Hardness} = \frac{\text{Amount of EDTA (Litres) x 1000}}{\text{Volume of sample taken}}$$

3.10 Determination of Chemical Water Quality

3.10.1 Nitrate

Into a cuvette, 0.01 litres of each of the water samples was transferred. NitraVer5 reagent was then added to each of the samples shaken to mix thoroughly and left to react for 5 minutes. The presence and concentrations of nitrate ions expressed in mg/L in the water samples was then read from the Ultra Violet Spectrophotometer at 500 nm.

3.10.2 Nitrite

Into a cuvette, 0.01 litres of each sample was transferred. NitraVer3 reagent was then added to each of the samples, shaken to mix thoroughly and left to react for 20 minutes. The presence and concentrations of nitrite ions expressed in mg/L in the water samples was then read from Ultra Violet Spectrophotometer at 507 nm.

3.10.3 Phosphate

Into a cuvette, 0.025 litres of each sample was transferred and then 0.001 litres of molybdovanadate reagent was added to each of the sample, shaken to mix thoroughly and left to react for 7 minutes. The presence and concentrations of phosphate ions in expressed in mg/L in the water samples was then read from the Ultra Violet Spectrophotometer at 430 nm.

3.10.4 Chloride

Into a cuvette, 0.01 litres of each sample was transferred, 0.001 litres of mercuric thiocyanate solution was then added to each of the samples and shaken to mix thoroughly. Then 0.0005 litres of ferric iron solution was added and mixed well and left to react for 2 minutes. The presence and concentrations of chloride ions expressed in mg/L in the water samples was then read from the Ultra Violet Spectrophotometer at 455 nm.

3.10.5 Sulphate

Into a cuvette, 0.01 litres of each sample was transferred, SulfaVer4 reagent was then added to each of the samples then shaken thoroughly to mix and left to react for 5minutes. The presence and concentrations of sulphate ions expressed in mg/L in the water samples was then read from the Ultra Violet Spectrophotometer at 450 nm.

3.10.6 Fluoride

Into a cuvette, 0.01 litres of each of the sample was transferred and then 0.002 litres of the spadns reagent was carefully added, mixed thoroughly and allowed one minute to react. The presence and concentrations of fluoride ions expressed in mg/L in the water samples was then read from the Ultra Violet Spectrophotometer at 580 nm.

3.10.7 Sodium and Magnesium

Into a 0.25 litres conical flask with a magnetic stirrer, 0.1 litres of each of the sample was transferred, 0.005 litres of concentrated nitric acid was then added. The sample was then heated on a hot plate to a slow boiling for 1 hour after which it was cooled. Each of the samples was then transferred into a 0.25 litre volumetric flask, topped up to the mark with grade1 purified water and thoroughly mixed. The 0.02 litres of each sample was aspirated into a Flame Atomic Absorbance Spectrophotometer (AAS) to determine presence and concentrations of sodium and magnesium ions in the water samples. Test results in mg/L were measured at 589 nm and 285 nm respectively. The same amount of grade1 purified water was treated as the samples and used as the blank.

3.11 Determination of Heavy Metals Water Quality

3.11.1 Iron, Cadmium, Manganese, Zinc, Chromium and Lead

Into a 0.25 litres conical flask with a magnetic stirrer, 0.1 litres of each of the sample was transferred and 0.005 litres of concentrated nitric acid was then added. The sample was then heated on a hot plate to a slow boiling for 1 hour after which it was cooled. Each of the samples was then transferred into a 0.25 litre volumetric flask, topped up to the mark with grade1 purified water and thoroughly mixed. The 0.02 litres of each sample was aspirated into a Flameless Atomic Absorbance Spectrophotometer (AAS) to determine presence and concentrations of iron, cadmium, manganese, zinc, chromium and lead in the water samples. The test results in mg/L were measured at 248 nm, 228 nm, 279 nm, 213 nm, 357 nm and 217 nm respectively. The same amount of grade1 purified water was treated as the samples and was used as the blank.

3.12 Determination of Bacteriological Water Quality

3.12.1 Total Coliform

1. Three sets of marctney bottles were used for each of the samples for dilutions of 10^{-1}, 10^{-2} and 10^{-3} respectively.
2. Into each of the marctney bottles, 0.009 litres of the macconkey solution was added.
3. An inverted Durham tube was inserted into each of the marctney bottles.
4. The media and the two marctney bottles each containing 0.009 litres of distilled water for the 10^{-2} and 10^{-3} dilutions for each of the sample were sterilized by autoclaving and then cooled.
5. A series of dilutions were prepared by transferring 0.001 litre of the sample to the 10^{-2} dilution bottle, then transferring 0.001 litres from the 10^{-2} to the bottle for the 10^{-3} dilution.
6. To the 10^{-1} dilution, 0.001 litres of 10^{-2} dilution to the 10^{-2} media and 0.001 litre of 10^{-3} dilution to 10^{-3} media, 0.001 litres of each of the samples were inoculated.
7. Each sample was then incubated at 37^{o} C for 48 hours.
8. A change of color of the media from purple to yellow and accumulation of gas in the Durham tube was observed for samples that tested positive for total coliform. Neither color change nor gas in the Durham tube was observed for samples that tested negative for total coliform.
9. The Most Probable Number (MPN) table was used to estimate the number of colony forming units.

3.12.2 Fecal Coliform

1. Into each of the marctney bottles representing the ones that tested positive for total coliform, 0.01 litres of the media was distributed.
2. The media was autoclaved and then cooled before inoculation.

3. Each of the total coliforms positive marctney bottles was inoculated to the respective marctney bottle containing 0.0001 litres of bacteriological peptone and incubated for 24 hours at 44.5^{o} C.
4. After incubation 2-3 drops of kovacs reagent were then added to each of the samples.
5. A pink ring was indicative of positive for fecal coliform.
6. The MPN table was used to estimate the number of colony forming units.

3.13 Data Analysis

The data gathered from the study was analyzed using Statistical Package for Social Scientists (SPSS). Data was expressed in terms of descriptive statistics such as percentages and average. The analyzed data was used to assess the sources and quality of drinking water; physico-chemical, chemical, heavy metals and bacteriological for residents of Kuria West. The analyzed data was also used to relate back to the experiences and views of the respondents to the finding of the available literature on the subject matter.

The quality of drinking water from the selected sources was determined by comparing the values obtained from the study with recommended values in KS-EAS 12-2014, **(**Kenya Bureau of Standards, 2014). In order to determine the samples that did not comply with the guideline values, basic statistical parameters such as percentages, minimum, maximum, and average values were used to analyze the data and to evaluate the dispersion of values for each of the parameters. Statistical evidence was used to provide additional information on analytical results.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1. 1 Demographics

The demographic characteristics of the residents of Isibania were determined as per section 3.8, and the results presented as below:

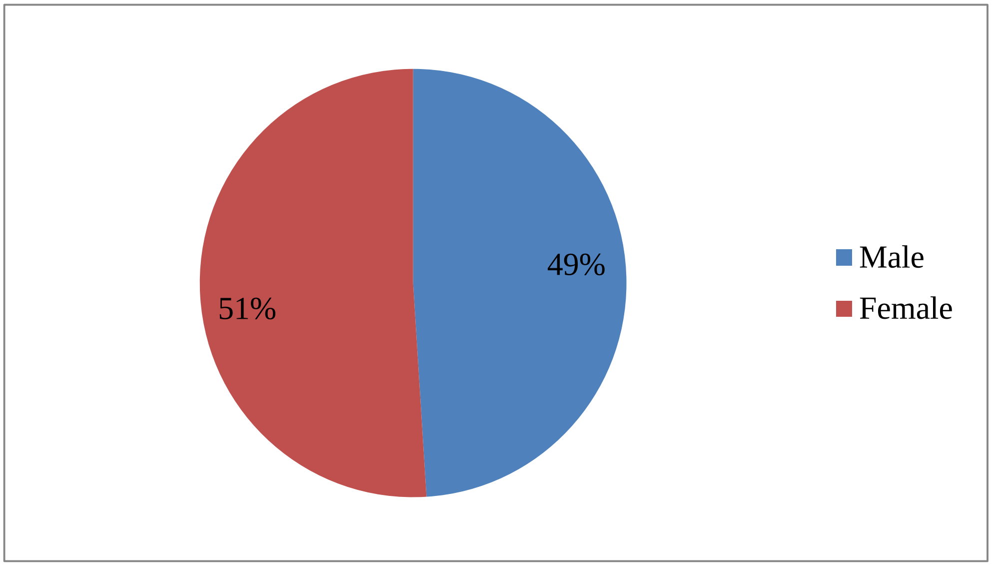


Figure 4.1.1 (a): Gender of the Respondents

51% of the respondents were female while 49% were male. The official government statistics for Kuria West is 52% female and 48% male, (Kenya National Bureau of Statistics, 2019). This implies that the views and concerns expressed by the respondents on drinking water sources and quality challenges is a fair representation of gender diversity in Kuria West.

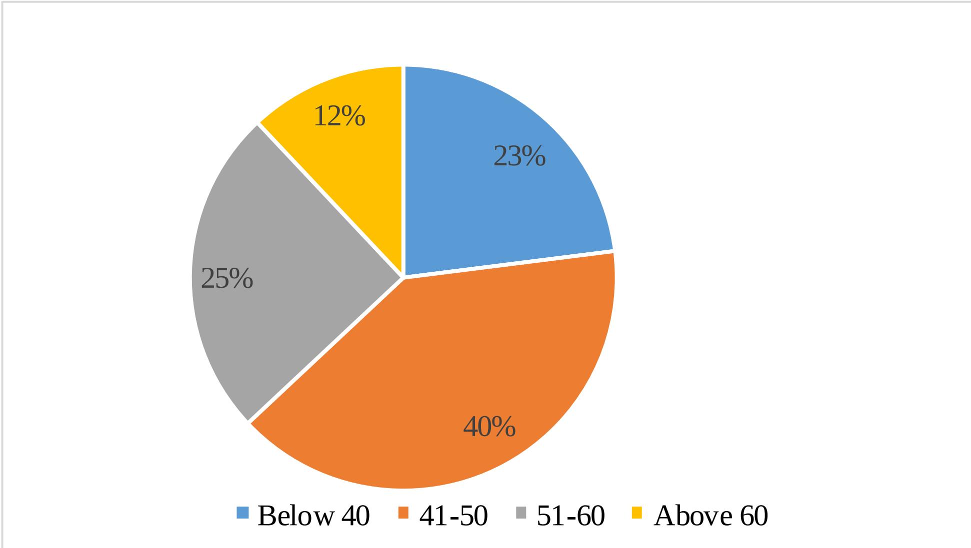


Figure 4.1.1 (b): Age in bracket in years of the respondents.

65% of heads of the respondents were aged between 40 and 60 years, this implies that a majority of the respondents had probably lived in the area for more than 5 years as adults and had experienced water shortages or quality challenges in Isibania.

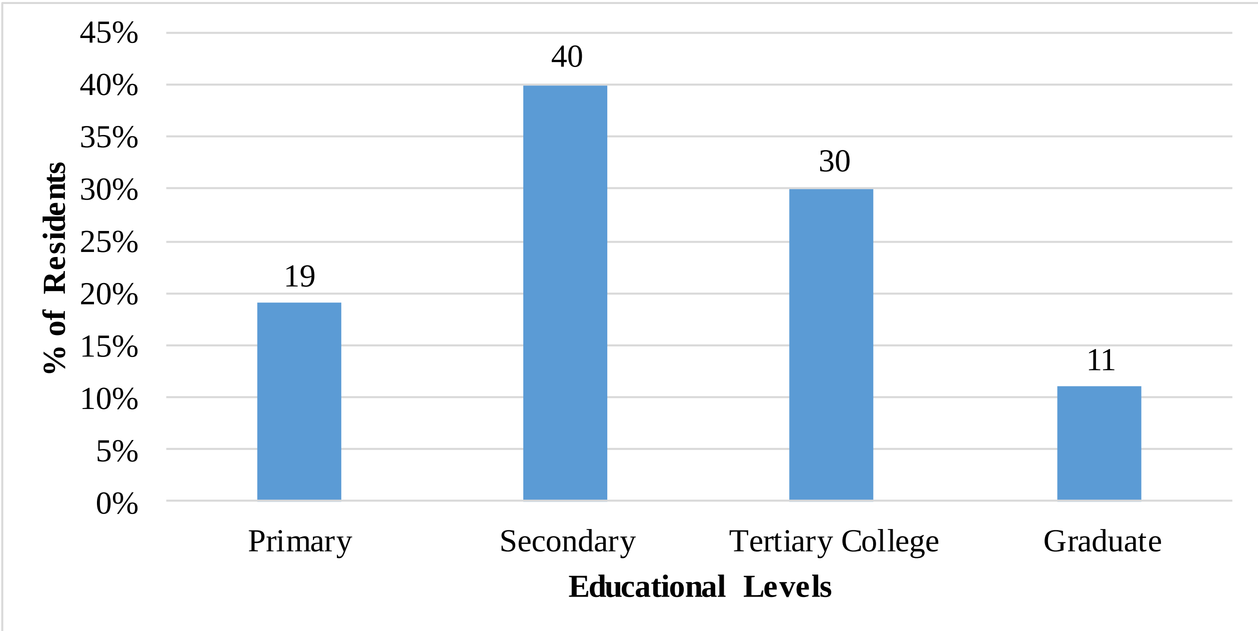


Figure 4.1.1 (c): Highest educational level of the respondents.

81% of heads of the respondents had attained at least secondary level of education. This implies that a majority of the respondents were literate enough to understand the sources of drinking water quality challenges. In addition they would be amenable to scientifically researched solutions of mitigation measures and participate in their implementations.

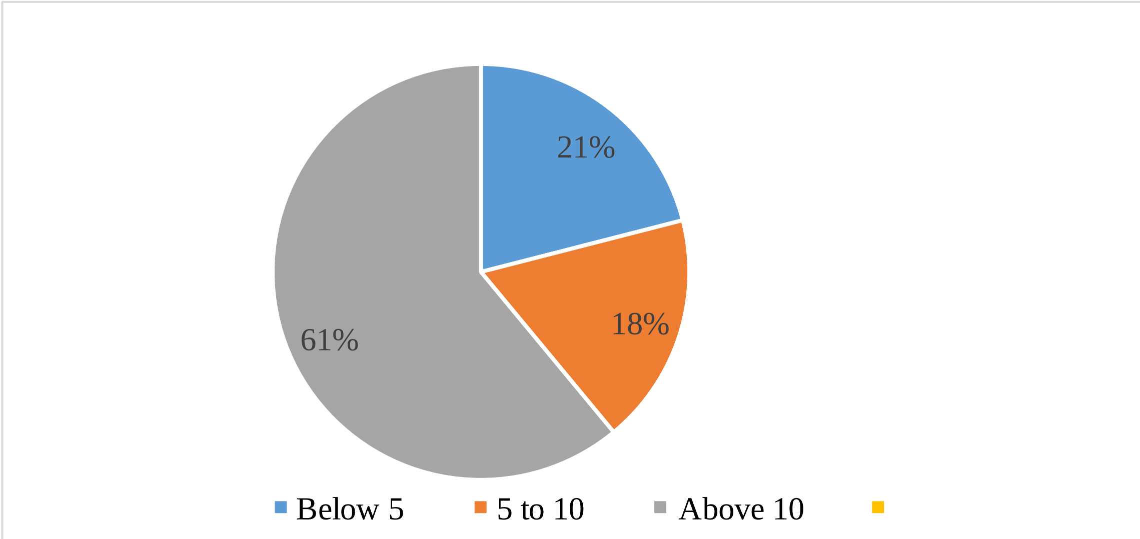


Figure 4.1.1 (d): Period in years lived in Kuria West.

79% of the respondents had lived in Kuria West for more than 5 years. This implies that a majority of the residents had lived in Kuria west long enough to have credible data about their drinking water sources and quality. They would also give suggestions on how to improve these sources and participate in community based point of drinking water sources treatment systems.

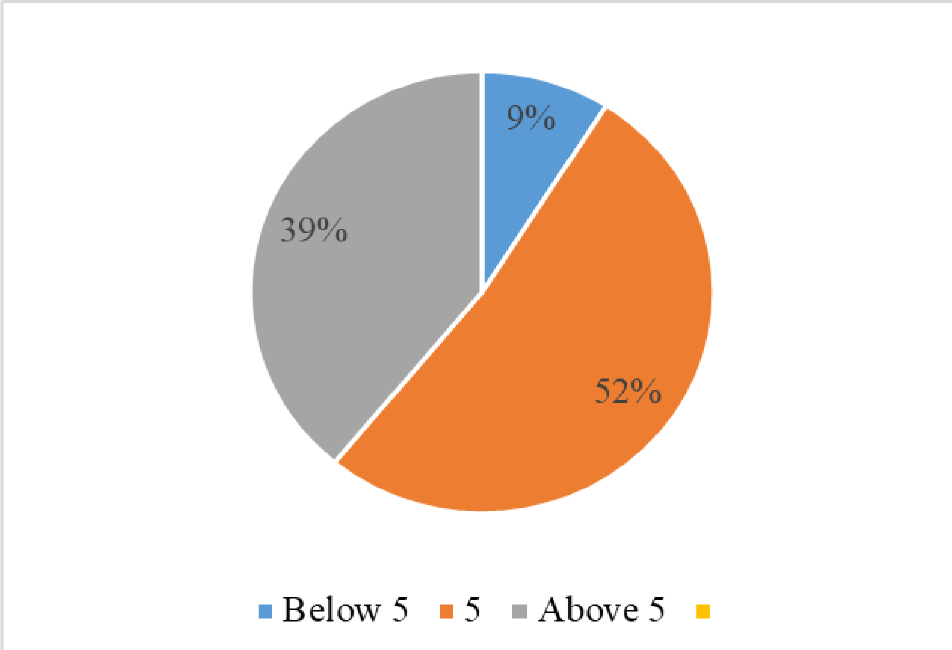


Figure 4.1.1 (e): Sizes of households of the respondents

52% of the respondents' households' had 5 members. The official government statistics of Kuria West indicates that the average number of members per households is 5.2, (Kenya National Bureau of Statistics, 2019). This implies that a majority of the households had significant numbers of members and would require sustainable sources of quality drinking water. They would also give diverse views on drinking water quality challenges in Kuria West.

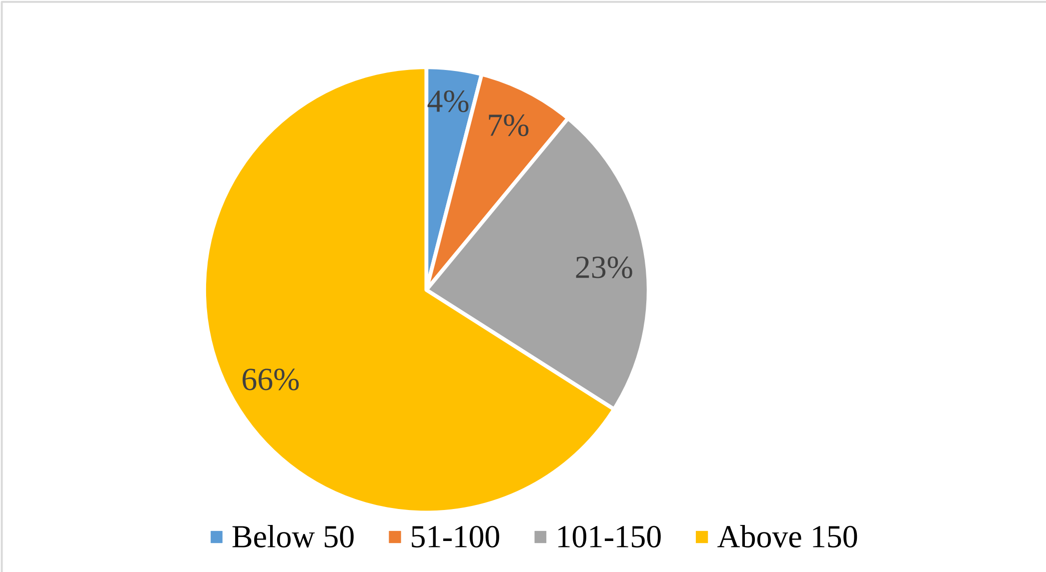


Figure 4.1.1(f): Daily households water requirements in litres.

89% of the households had daily drinking water requirement of at least 100 litres. This implies that a majority of the households consumes a substantial amount of drinking water, there is need to address this high demand. Additionally they would be aware of their sources of drinking water its and quality challenges.

4.1.2 Drinking Water Sources

The drinking water sources were determined as per section 3.8 and the results presented in figure 4.1.2.

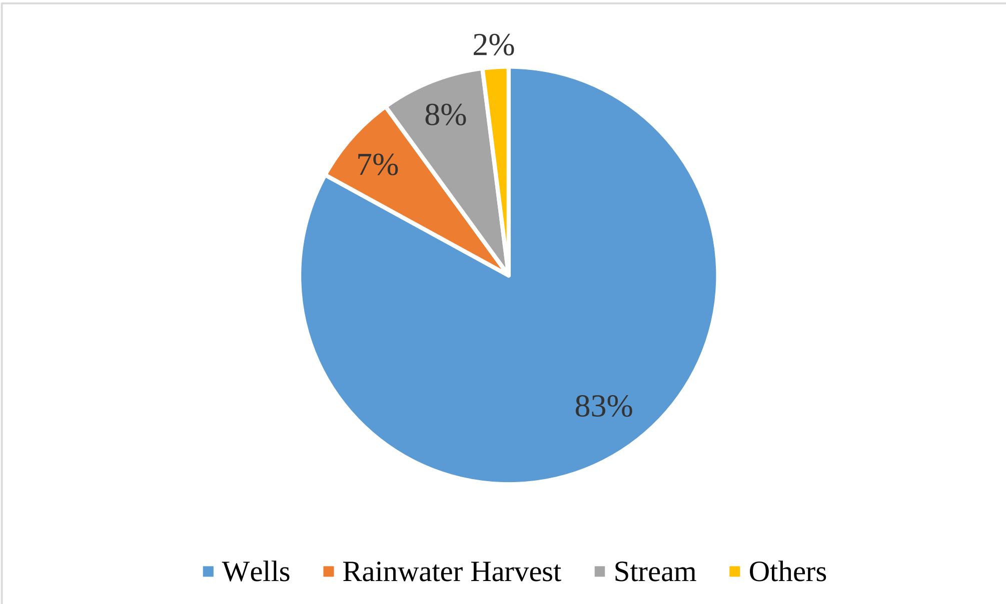


Figure 4.1.2: Sources of drinking water for the residents

98% of the residents depended on wells, rainwater harvest and streams as sources of drinking water. This implies that a majority of the residents would be aware of quality challenges of drinking water from these sources.

4.2. Physico-chemical Water Quality

4.2.1 pH

The pH values of the water samples were determined as per section 3.9.1 and the results presented in figure 4.2.1.

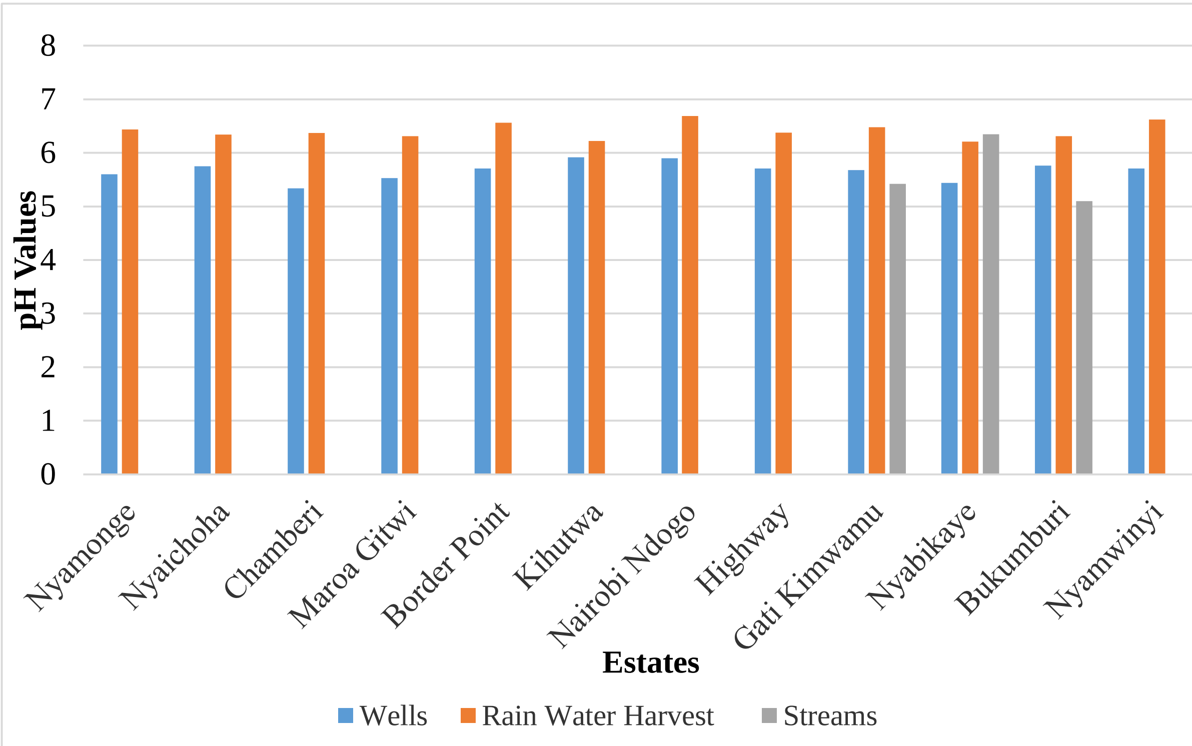


Figure 4.2.1: pH values of drinking water from selected sources.

The pH values ranged from 5.31 to 6.69, Chamberi and Nyabikaye wells, Gati Kimwamu and Bukumburi streams had an average pH value of 5.33 which is below the lower limit of 5.5 for natural portable for water. This implies that these sources are contaminated; water is unpalatable for drinking purposes and is a contributing factor of its consumer evasion.

4.2.2 Total Dissolved Solids

Total dissolved solids of the water samples were determined as per section 3.9.2 and the results presented in Figure 4.2.2

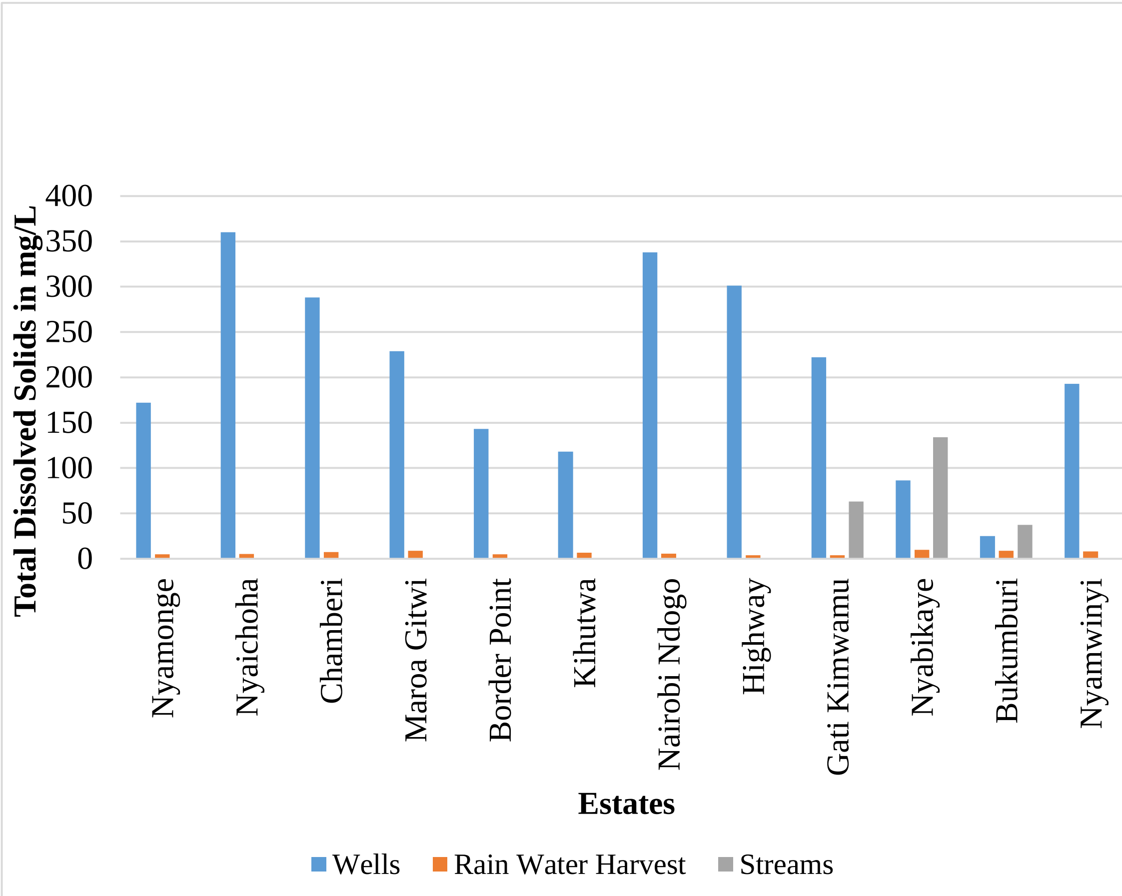


Figure 4.2.2: Total dissolved solids in mg/L of drinking water from selected sources

Total dissolved solids values were obtained all water samples ranging from 3.79 to 360 mg/L for Highway rainwater harvest and Nyaichoha well respectively. The Average values were 206.3, 6.5 and 50.2 mg/L for wells, rainwater harvest and streams respectively. These values were within the limit of 1500 mg/L for drinking water.

4.2.3 Total Alkalinity

The total alkalinity levels of the water samples were determined as per section 3.9.3 and the results presented in Figure 4.2.3.

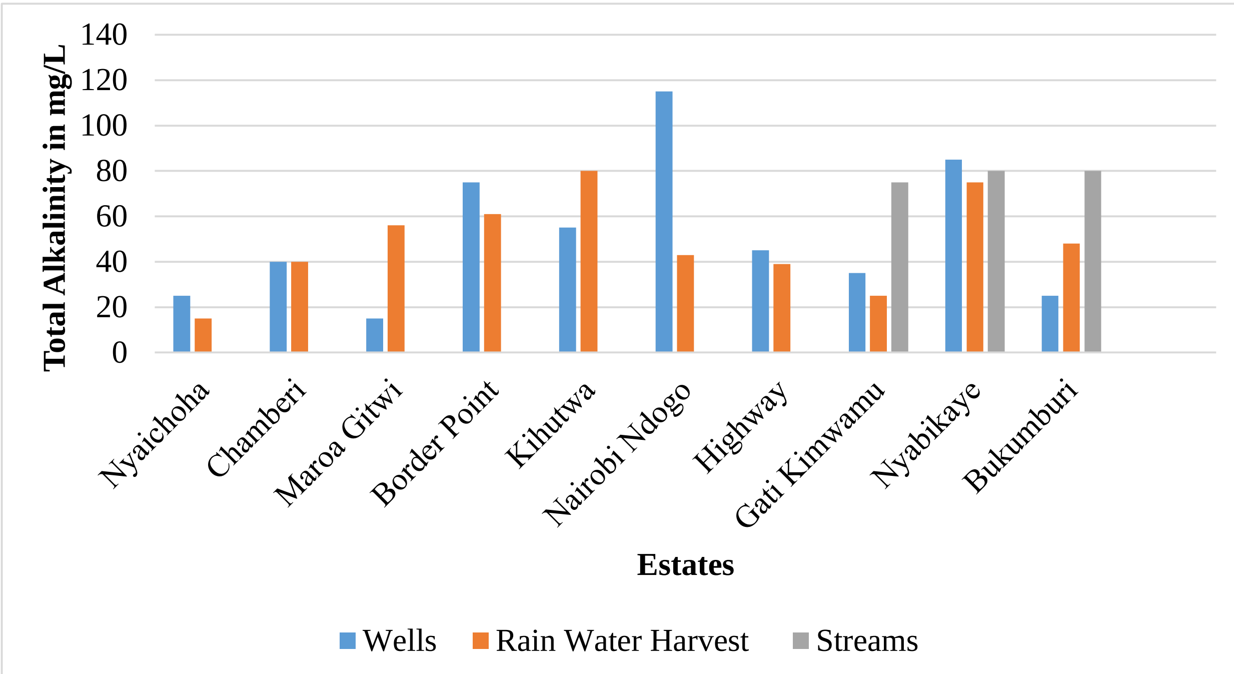


Figure 4.2.3: Total alkalinity levels in mg/L of drinking water from selected sources.

Total alkalinity values obtained ranged from 15 to 115 mg/L for Nyaichoha rainwater harvest Maroa Gitwi well and Nairobi Ndogo well respectively. The overall average value detected was 50.5 mg/L. These values were within the limit of 500 mg/L for drinking water.

4.2.4 Total Hardness

Total hardness of the water samples were determined as per section 3.9.4 and the results presented in Figure 4.2.4

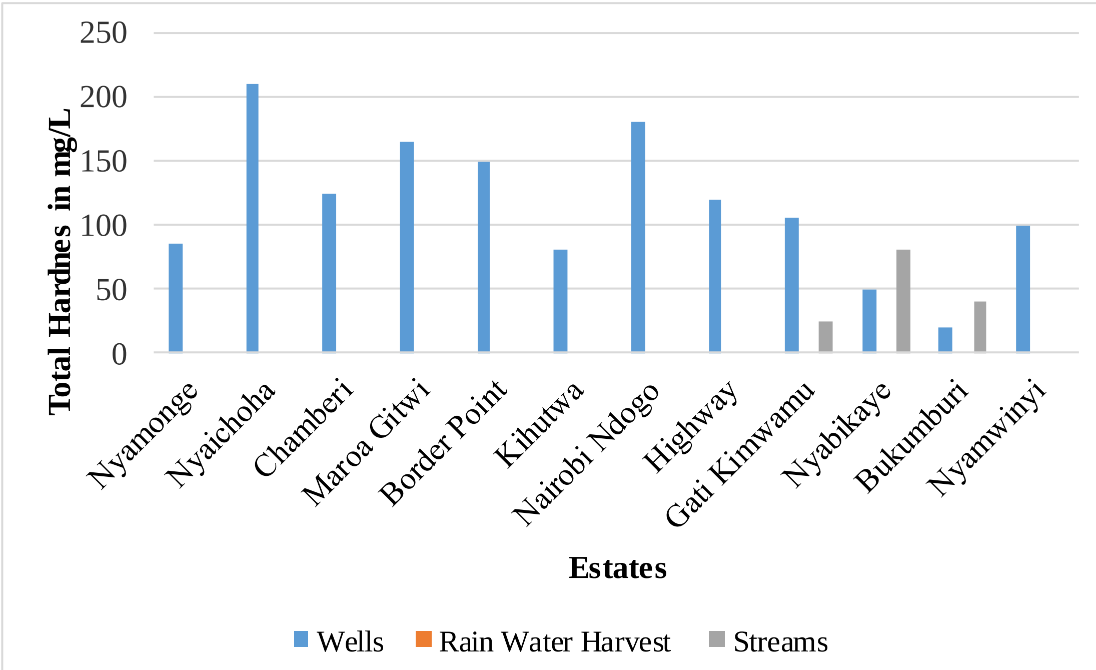


Figure 4.2.4: Total hardness levels in mg/L of drinking water from selected sources.

Total hardness values obtained ranged from 20 to 210 mg/L in water samples from Bukumburi well and Nyaichoha well respectively. The average values for wells and streams were 116.8 and 48.3 mg/L respectively. These values were within the limit of 600 mg/L for drinking water.

4.3 Chemical Water Quality

4.3.1 Nitrite

The concentrations of nitrite ions in the water samples were determined as per section 3.10.1 and the results presented in Figure 4.3.1

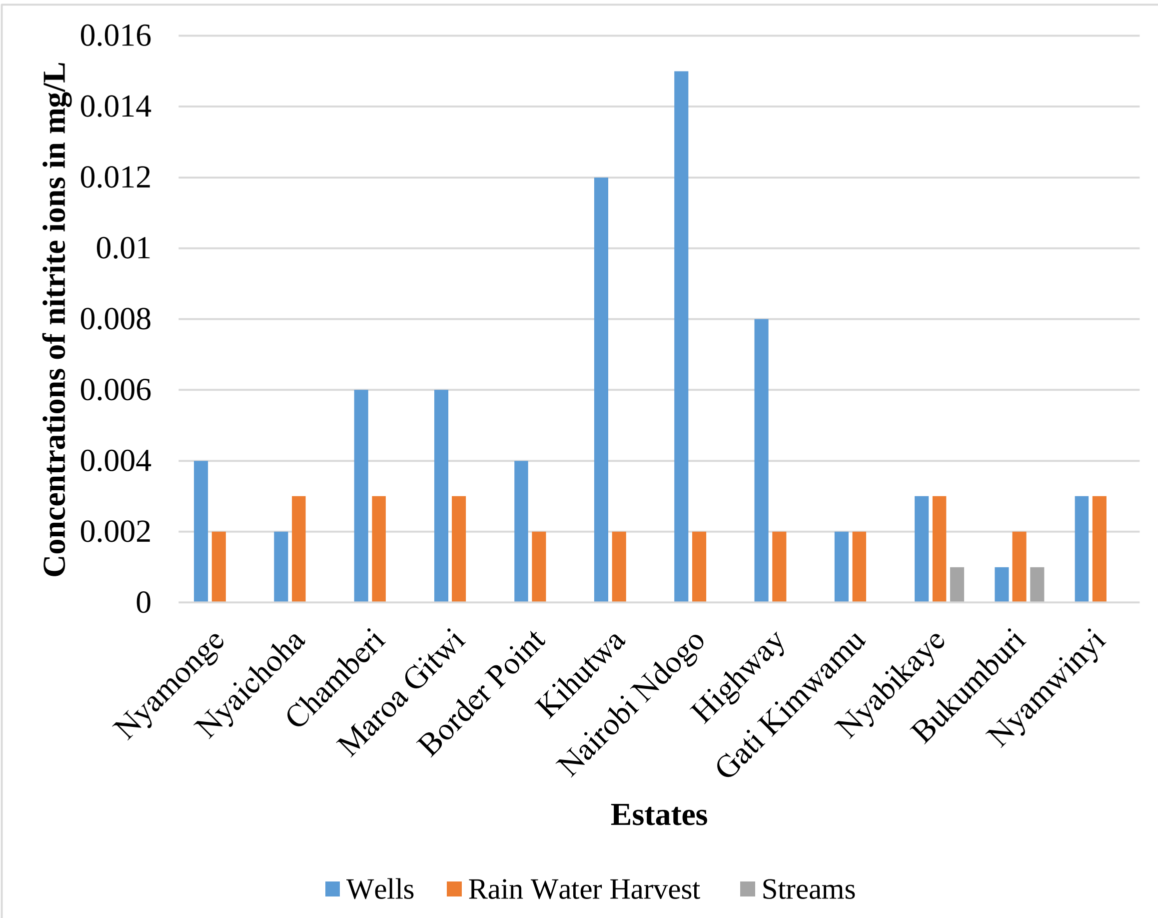


Figure 4.3.1: Concentrations of nitrite ions in mg/L in drinking water from selected sources.

Nitrite ions were detected in water samples at concentrations ranging from 0.001 to 0.015 mg/L. Water samples from 26% of the wells studied had average nitrite ions of 0.0056 mg/L which is above the limit of 0.003 for drinking water. It was inferred that these sources are polluted with nitrate compounds from waste disposal sites that are common in the estates.

4.3.2 Nitrate

The concentrations of nitrate ions in the water samples were determined as per section 3.10.2 and the results presented in Figure 4.3.2.

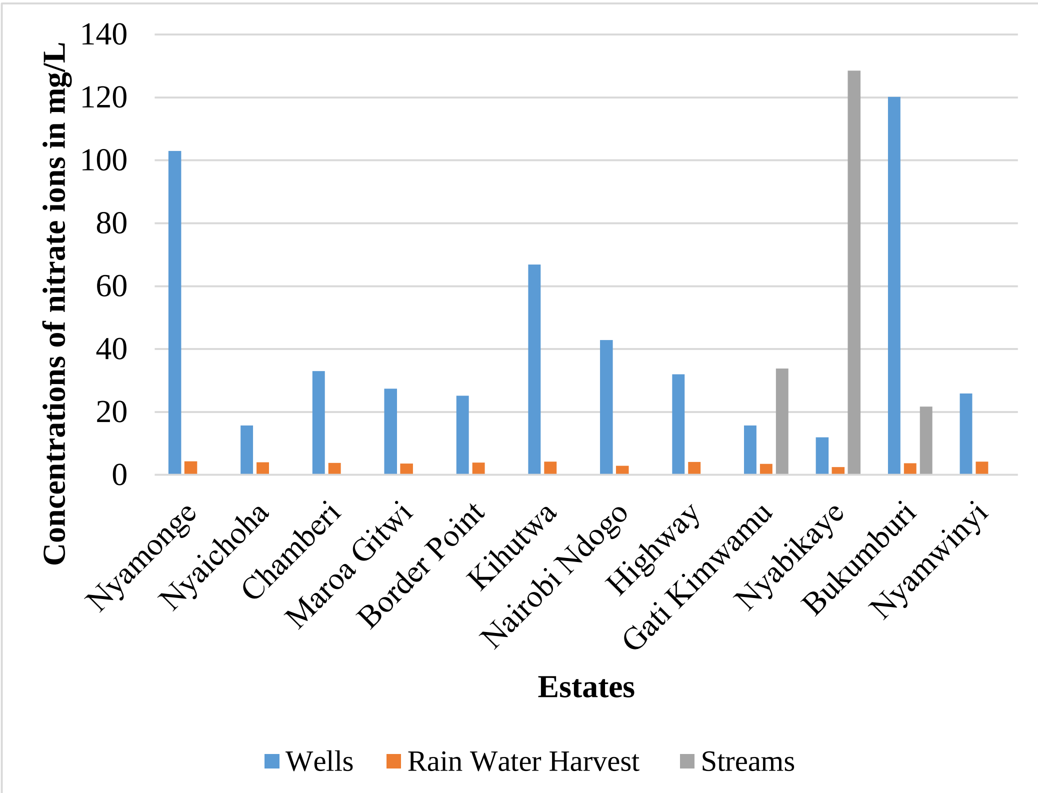


Figure 4.3.2: Concentrations of nitrate ions in mg/L in drinking water from selected sources.

Nitrate ions were detected in the water samples at concentrations ranging from 2.5 to 120 mg/L. Water samples from Nyamonge, Kihutwa and Bukumburi wells, and Nyabikaye stream had average nitrate ions of 79.5 mg/L which is above the limits of 45 for drinking water. It was inferred that Kihutwa and Nyamonge wells are polluted with nitrates from waste disposals sites that were common within the estates. The same pollution is attributed leaching and agrochemicals for Bukumburi well and Nyabikaye streams; the estates have numerous small scale farms.

4.3.3 Phosphate

The concentrations of phosphate ions in the water samples were determined as per section 3.10.3 and the results presented in Figure 4.3.3

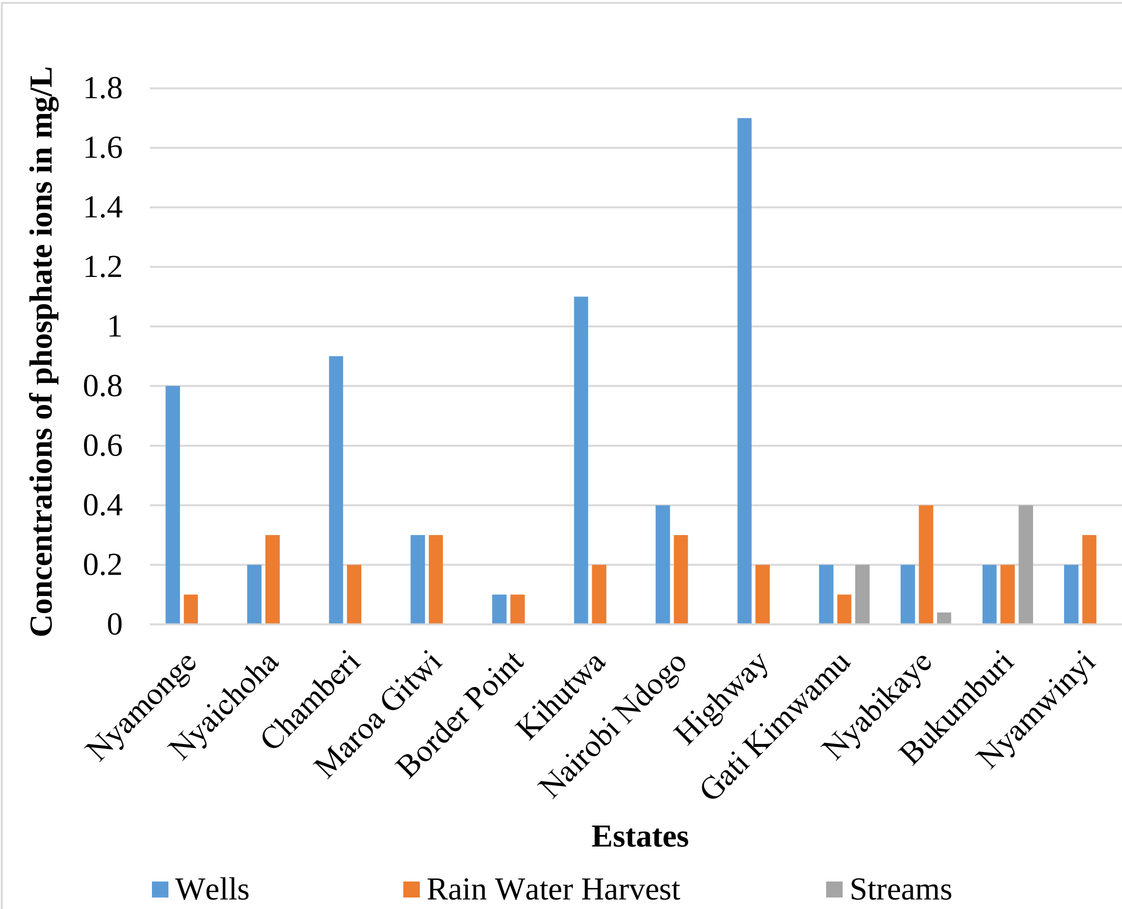


Figure 4.3.3: Concentrations of phosphate ions in mg/L in drinking water from selected sources.

Phosphate ions were detected in water samples from all the sources studied at concentrations ranging from 0.04 to 1.70 mg/L. All the values obtained are however within limit of 2.2 mg/L for drinking water.

4.3.4 Chloride

The concentrations of chloride ions in the water samples were determined as per section 3.10.4 and the results presented in Figure 4.3.4.

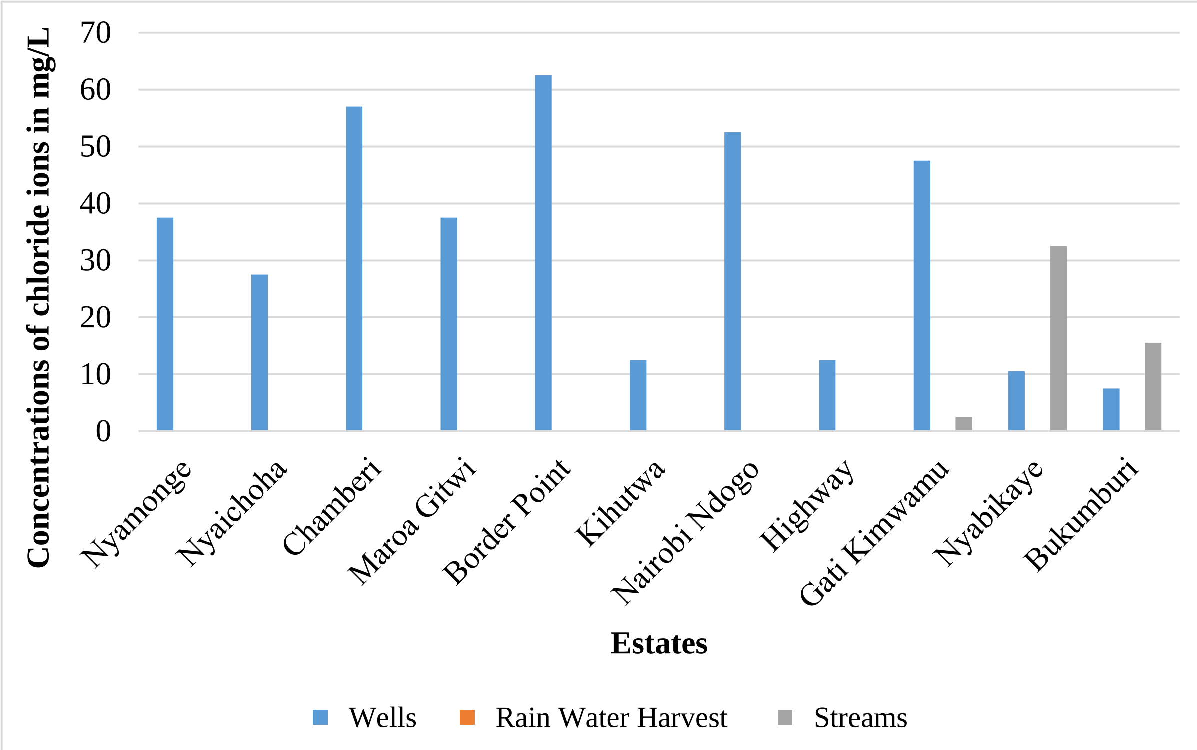


Figure 4.3.4: Concentrations of chloride ions mg/L in drinking water from selected sources.

Chloride ions were detected only in water samples from wells and streams studied at concentrations ranging from 2.50 to 62.50 mg/L. These concentrations were within the limit of 250 mg/L for drinking water.

4.3.5 Sulphate

The concentrations of sulphate ions in the water samples were determined as per section 3.10.5 and the results presented in Figure 4.3.5

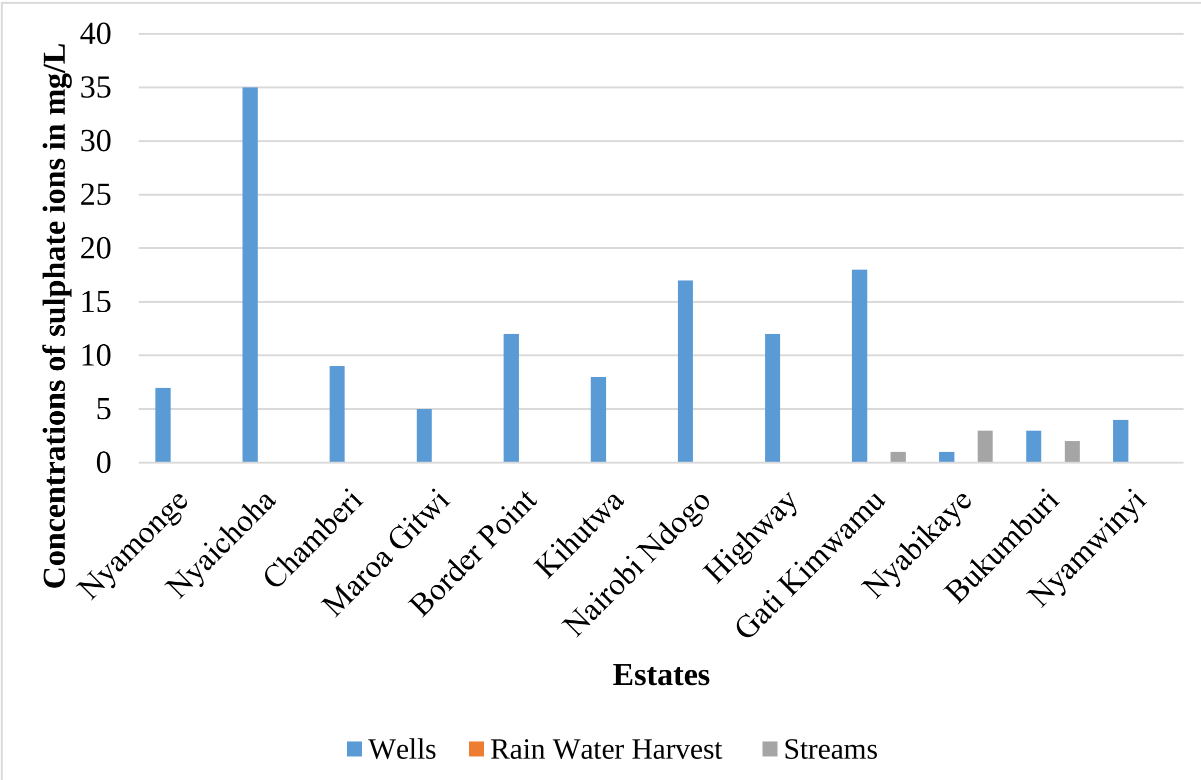


Figure 4.3.5: Concentrations of sulphate ions in mg/L in drinking water from selected sources.

Sulphate ions were detected in water samples from the wells and streams studied at concentrations ranging from 1.00 to 35 mg/L. These concentrations were within the limit of 400 mg/L for drinking water.

4.3.6 Fluoride

The concentrations of fluoride ions in the water samples were determined as per section 3.10.6 and the results presented in Figure 4.3.6

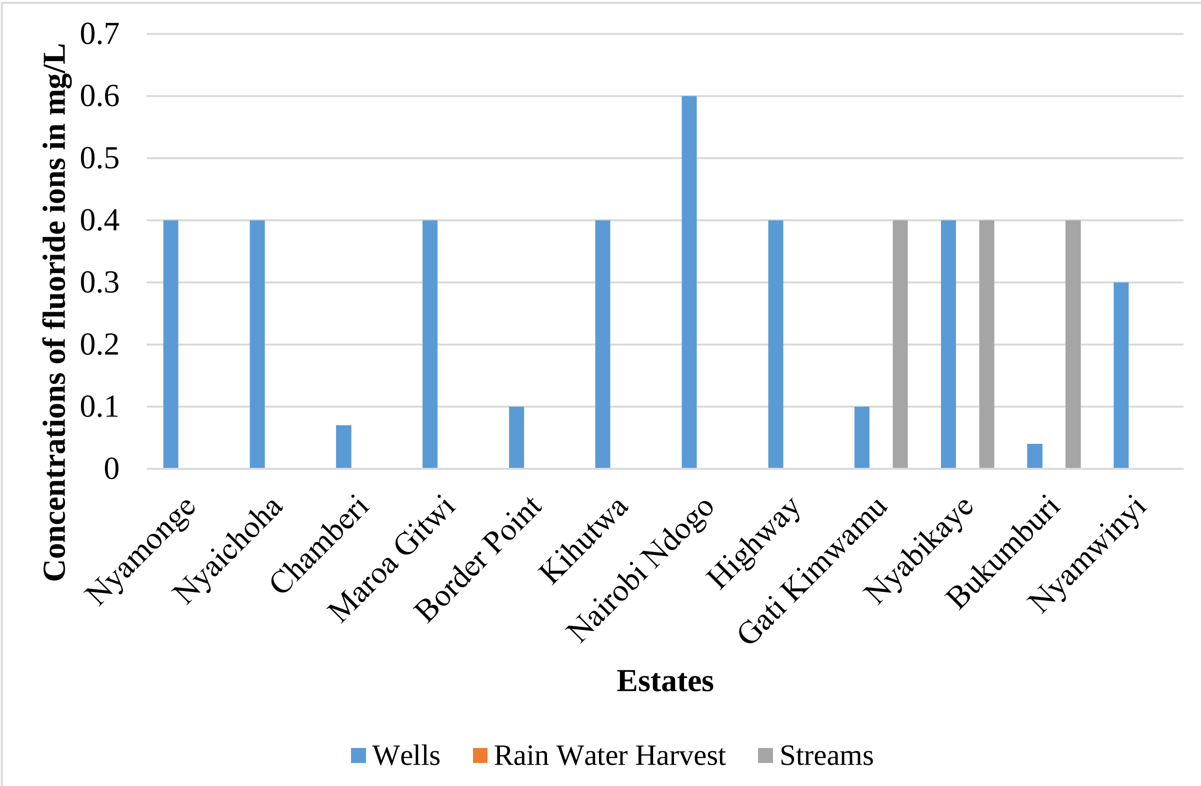


Figure 4.3.6: Concentrations of fluoride ions in mg/L in drinking water from selected sources.

Fluoride ions were detected only in water samples from wells and streams studied at concentrations ranging from 0.04 to 0.6 mg/L. These concentrations were within the limit of 1.5 mg/L for drinking water. Water samples from 52% of the sources studied had fluoride ions at concentrations lower than 0.5 mg/L; consumption provides protection against dental decay.

4.3.7 Sodium

The concentrations of sodium ions in the water samples were determined as per section 3.10.7 and the results presented in Figure 4.3.7

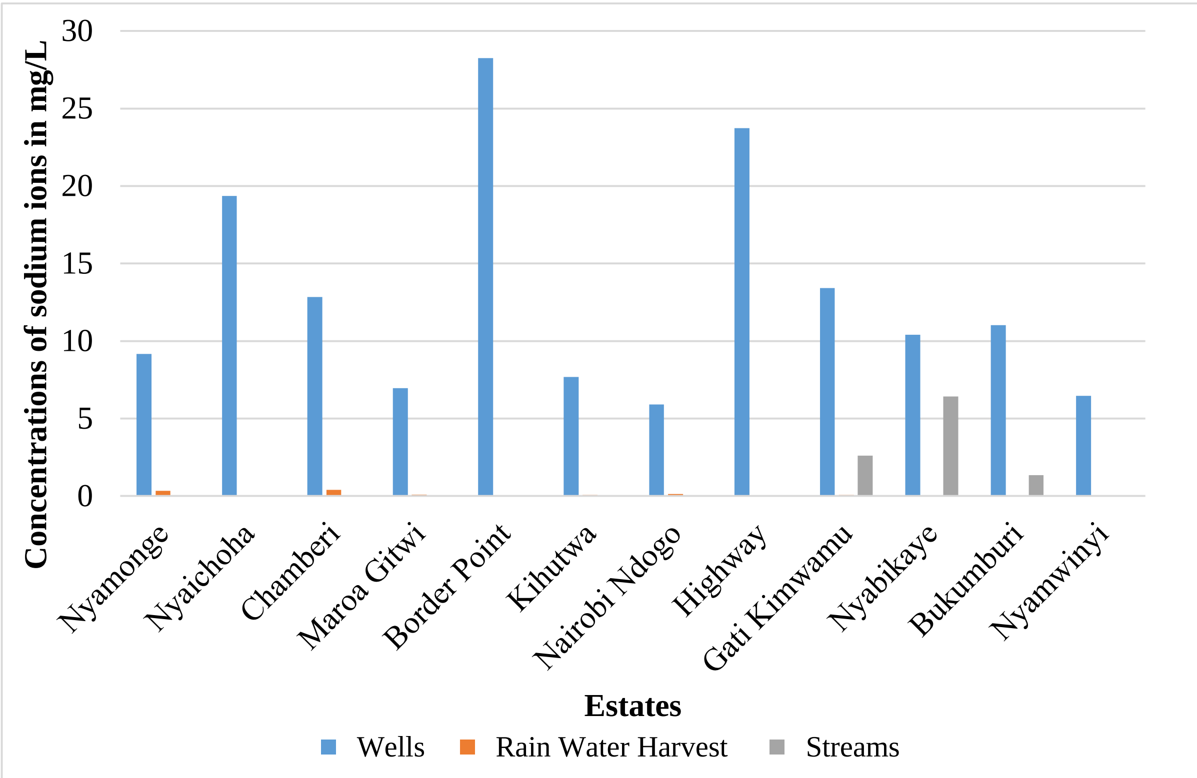


Figure 4.3.7: Concentrations of sodium ions in mg/L in drinking water from selected sources.

Sodium ions were detected in water samples from all the sources studied at an average concentration of 12.94, 0.17 and 3.46 mg/L for wells, rainwater harvests and streams respectively. These concentrations are within the limit of 200 mg/L for drinking water.

4.3.8 Magnesium

The concentrations of magnesium ions in the water samples were determined as per section 3.10.7 and the results presented in Figure 4.3.8

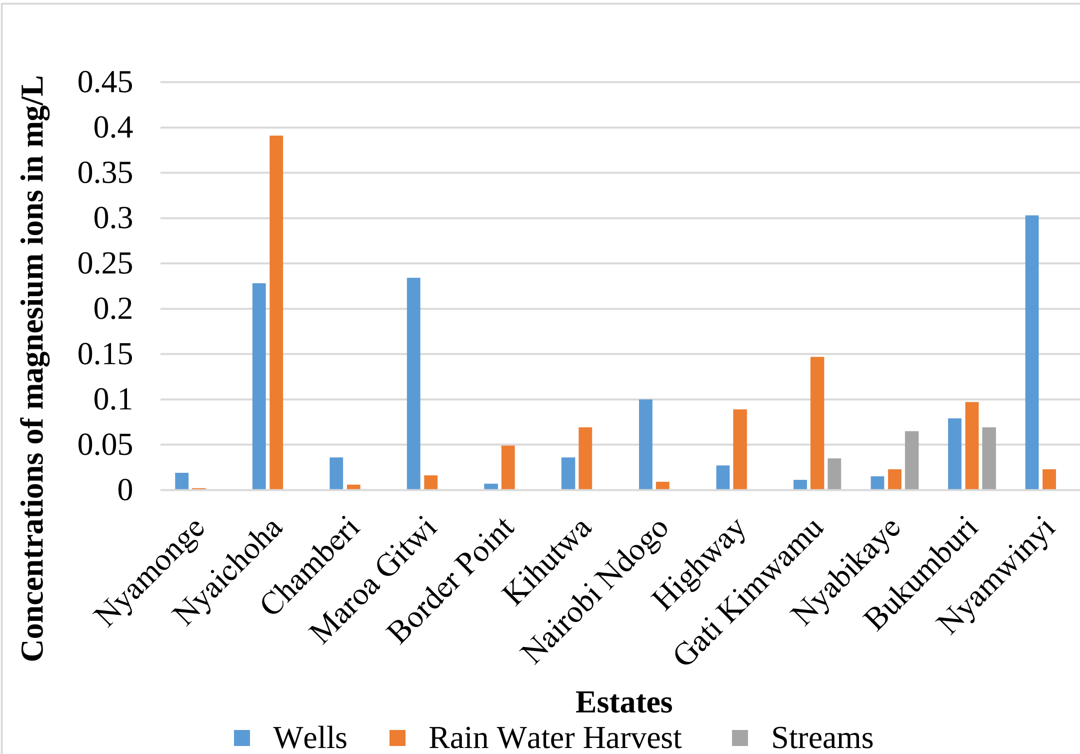


Figure 4.3.8: Concentrations of magnesium ions in mg/L in drinking water from selected sources.

Magnesium ions were detected in water samples from all the sources studied at concentrations ranging from 0.002 to 0.391 mg/L. These concentrations were within the limit of 100 mg/L for drinking water.

4.4 Heavy Metals Water Quality

4.4.1 Iron

The concentrations of iron ions in the water samples were determined as per section 3.11.1 and the results presented in Figure 4.4.1.

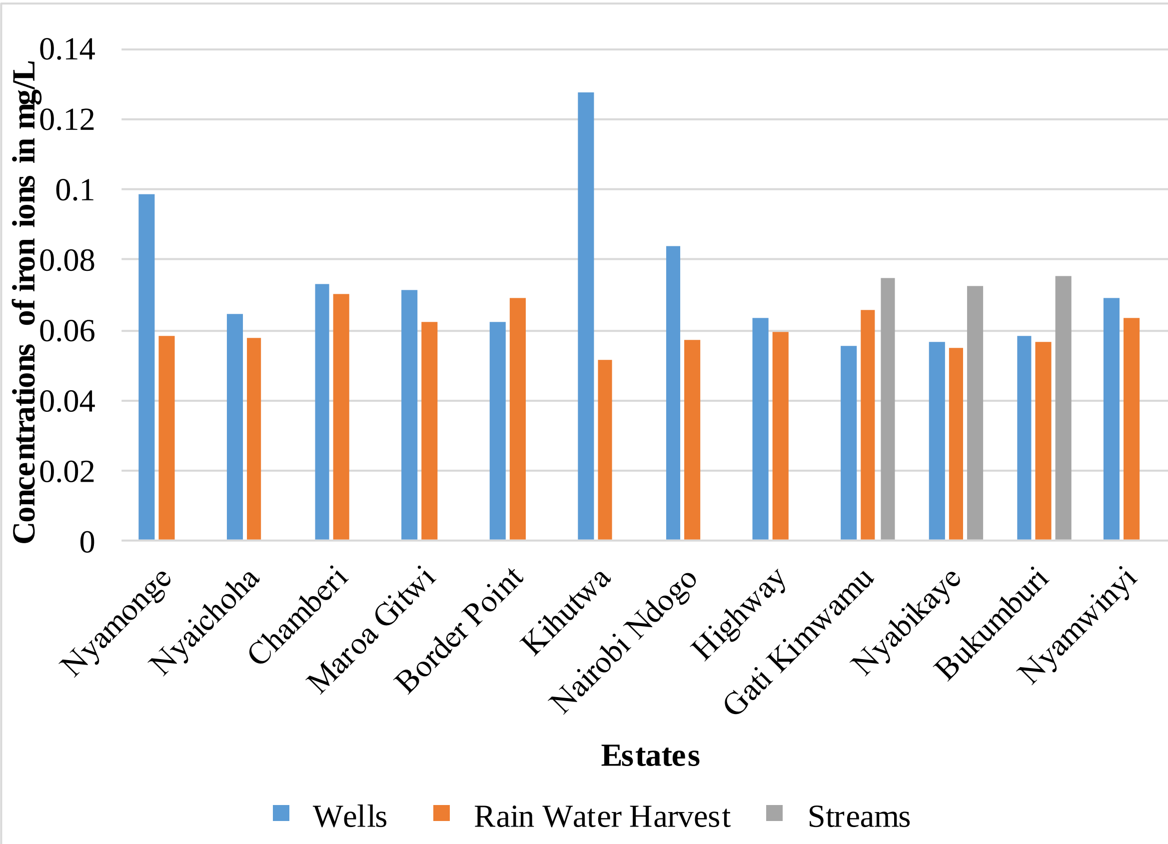


Figure 4.4.1: Concentrations of iron ions in mg/L in drinking water from selected sources.

Iron ions were detected in water samples from all the sources studied at concentrations ranging from 0.0515 to 0.128 mg/L. These concentrations were all within the limit of 0.3 mg/L for drinking water. Water sample from Kihutwa well had irons ions concentrations above the taste threshold of 0.1 mg/L; sources are from geological and chemical composition of the hydrological environment.

4.4.2 Cadmium

The concentration of cadmium ions in the water samples was determined as per section 3.11.1 at a limit of detection and qualification of 0.0001 and 0.0003 mg/L respectively. Cadmium was not detected in any of the samples from the drinking water sources studied. The acceptable cadmium concentration for drinking water is 0.003 mg/L.

4.4.3 Manganese

The concentrations of manganese ions in the water samples were determined as per section 3.11.1 and the results presented in Figure 4.4.3

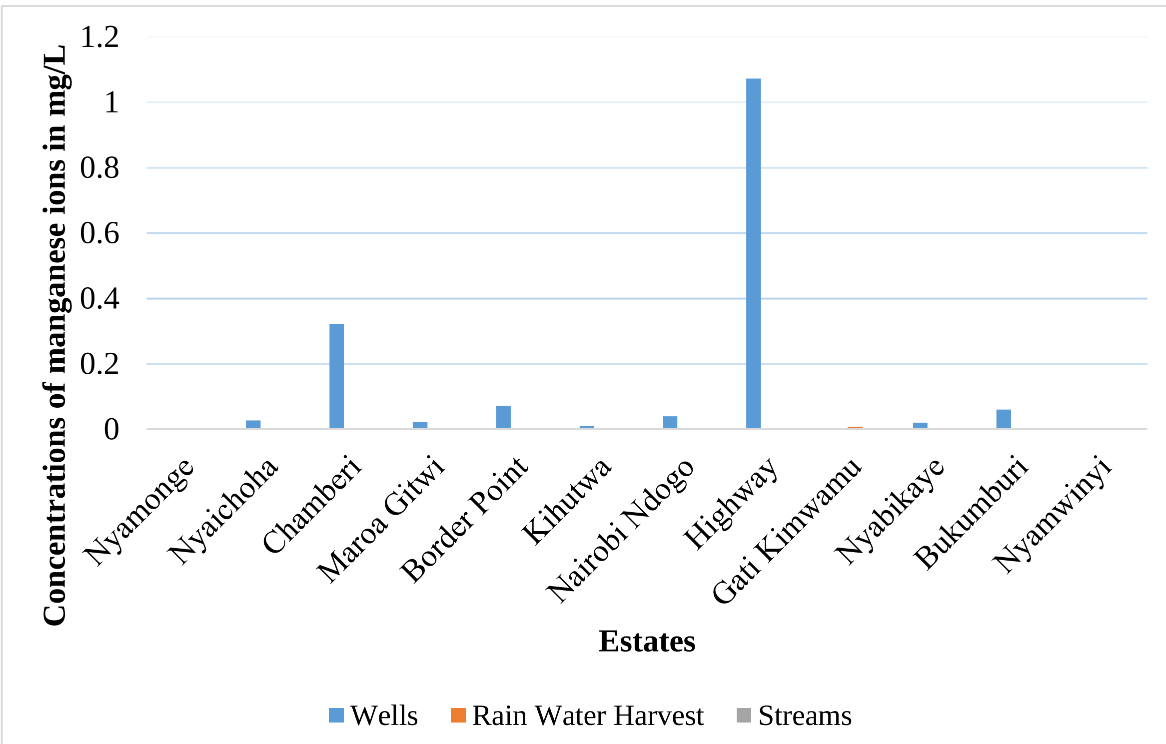


Figure 4.4.3: Concentrations of manganese ions in mg/L in drinking water from selected sources

Chamberi and Highway wells had manganese ions at concentrations of 0.322 and 1.07 mg/L respectively which were above the limits of 0.1 for drinking water. It was inferred that these sources are polluted with manganese emanating from agrochemicals disposals and leaching; small scale agricultural activities within the estates unlike in Nyamonge and Gati Kimwamu.

4.4.4 Zinc

The concentration of zinc ions in the water samples were determined as per section 3.11.1 and the results presented in Figure 4.4.4

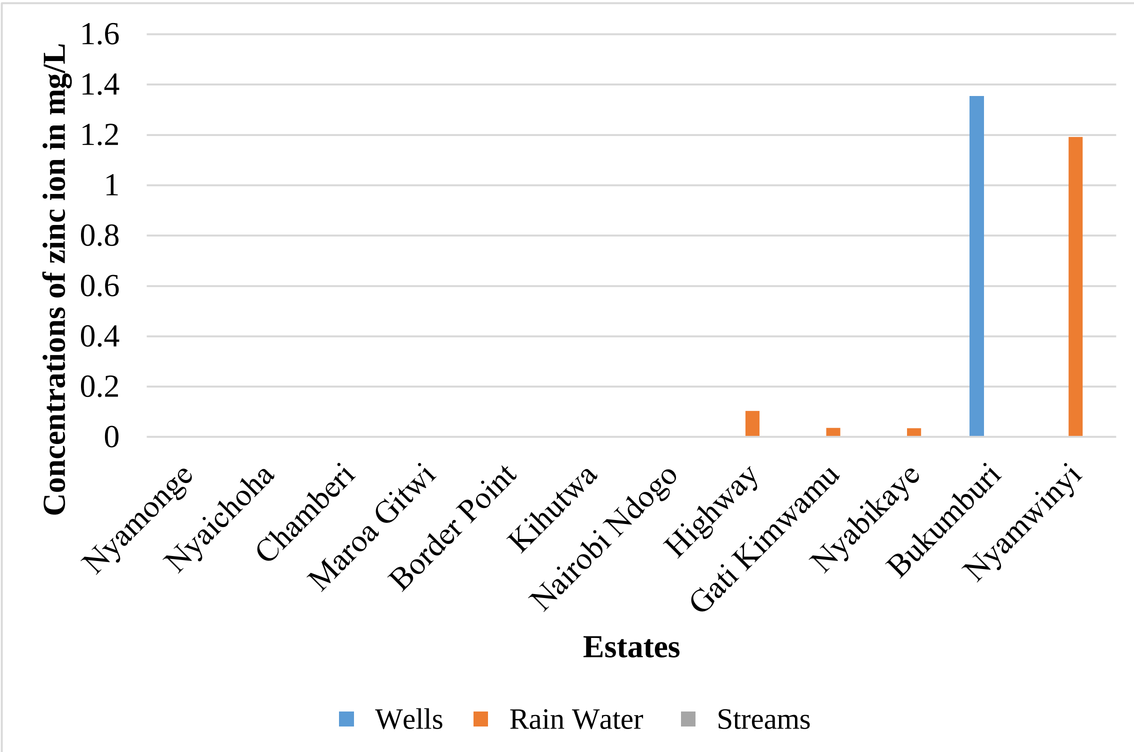


Figure 4.4.4: Concentrations of zinc ions in mg/L in drinking water from selected sources

Zinc ions were detected in samples from Bukumburi well and in Highway, Gati Kimwamu, Nyabikaye and Nyamwinyi rainwater harvest at concentrations of 1.353, 0.103, 0.036, 0.035 and 1.192 mg/L respectively. These concentrations were all within the limit of 5 mg/L for drinking water. The sources of zinc in wells are localized geochemical processes while in rainwater harvest is chemical reactions with the storage materials.

4.4.5 Chromium

The concentrations of chromium ions in the water samples were determined as per section 3.11.1 and the results presented in Figure 4.4.5

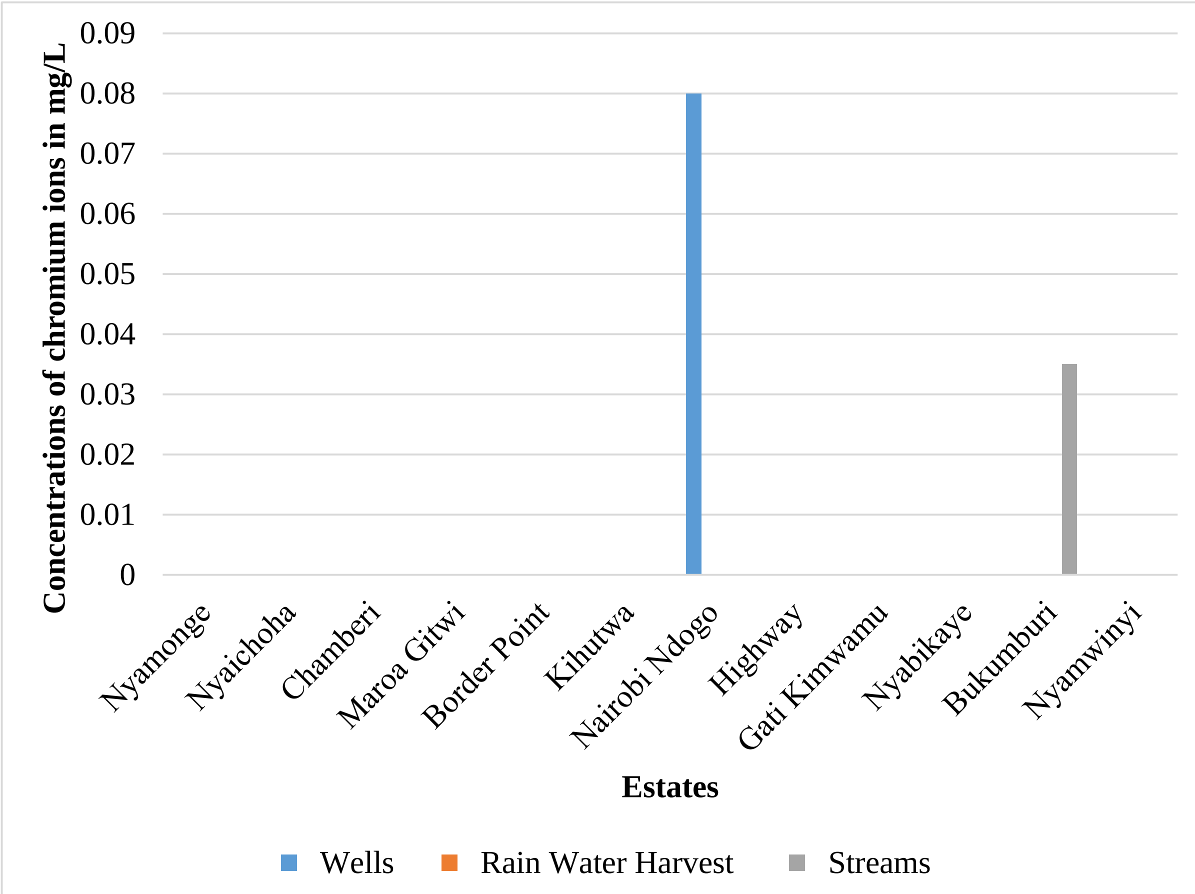


Figure 4.4.5: Concentrations of chromium ions in mg/L in drinking water from selected sources

Chromium ions were detected in samples from Nairobi Ndogo well and Bukumburi stream at concentrations of 0.08 and 0.035 mg/L respectively. The concentration of the Nairobi Ndogo well is above the limit of 0.05 mg/L for natural portable water. It was inferred that the sources are contaminated with chromium emanating from leaching and waste disposals; small scale informal metalwork and motor vehicle repair enterprises that involved painting were common within the estates

4.4.6 Lead

The concentrations of lead ions in the water samples were determined as per section 3.11.1 and the results presented in Figure 4.4.6

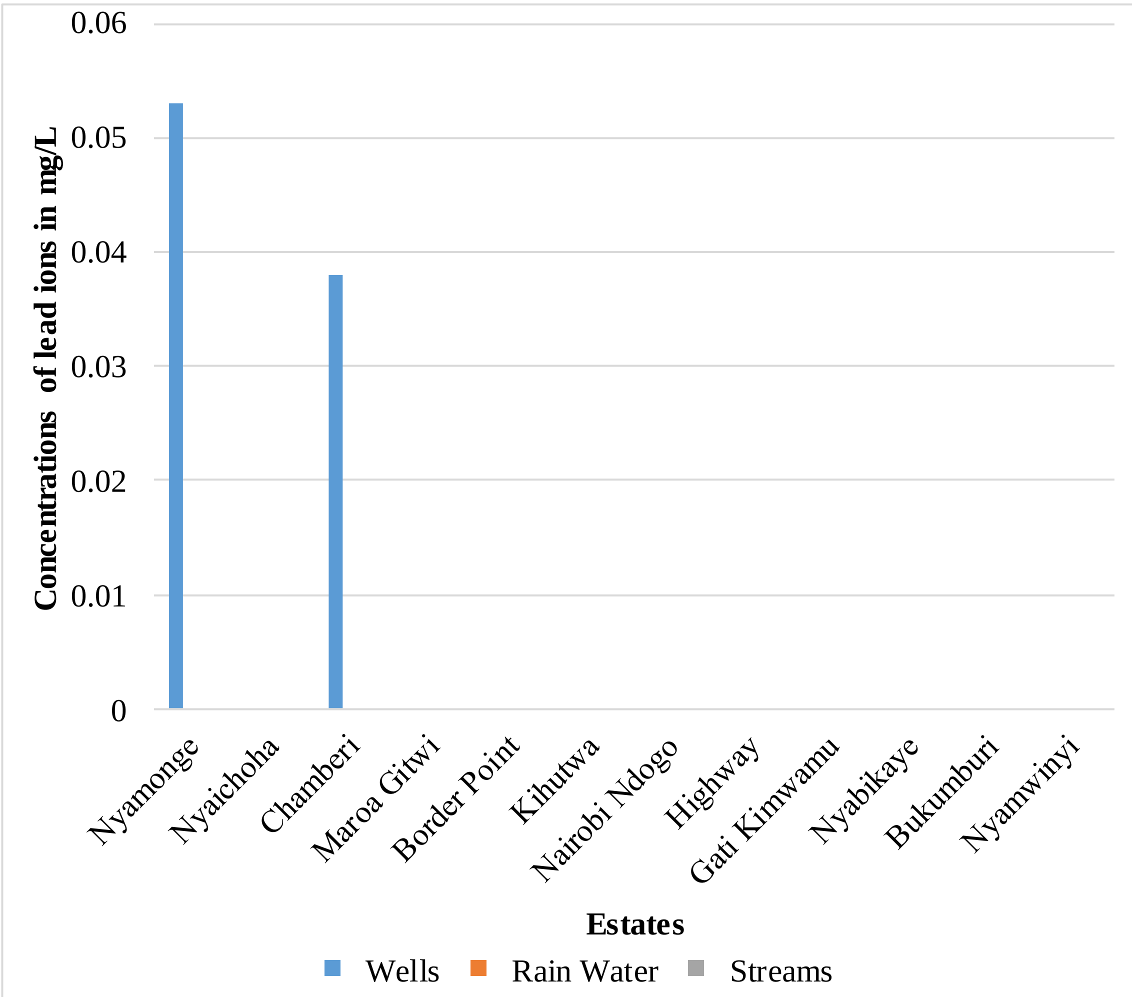


Figure 4.4.6: Concentrations of Lead ions in mg/L in drinking water from selected sources.

Lead was detected only in samples from Nyamonge and Chamberi wells at concentrations of 0.053 and 0.038 mg/L respectively. These concentrations are above the limit of 0.001 mg/L for drinking water. It was inferred that these sources are contaminated with lead from leaching and localized geochemical processes.

4.5 Bacteriological Water Quality

4.5.1 Total Coliform

The presence of total coliform in the water samples were determined as per section 3.12.1 and the results presented in Figure 4.5.1

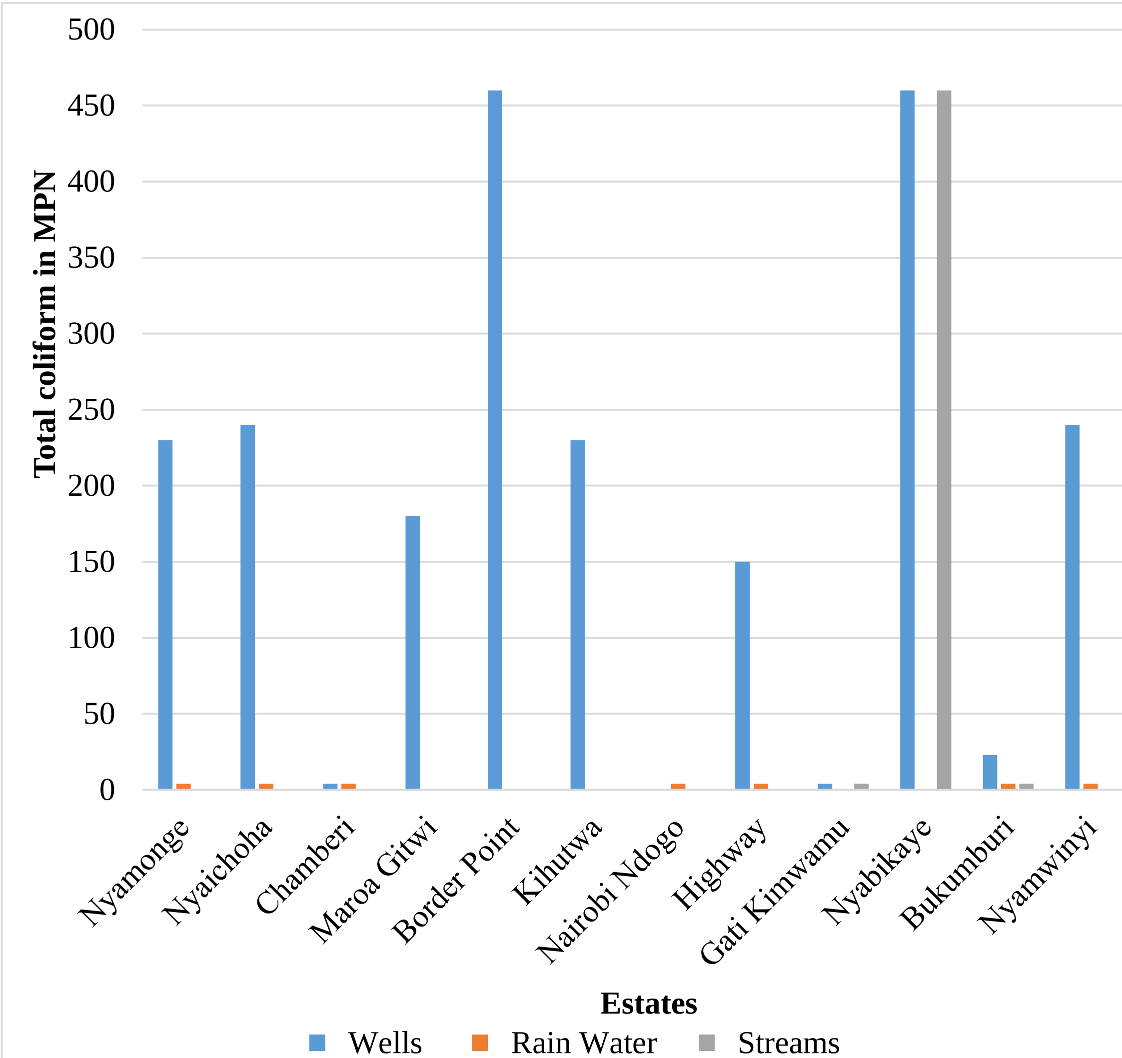


Figure 4.5.1: Total coliform in MPN in drinking water from selected sources.

Water samples from 78% of the sources studied did not conform to quality standards of nil total coliform. It was inferred that water from these sources are contaminated with harmful microbes and are prone to seepage from pit latrines and to biological waste disposals.

4.5.2 Fecal Coliform

The presence fecal coliform in the water samples were determined as per section 3.12.2 and the results presented in Figure 4.5.2

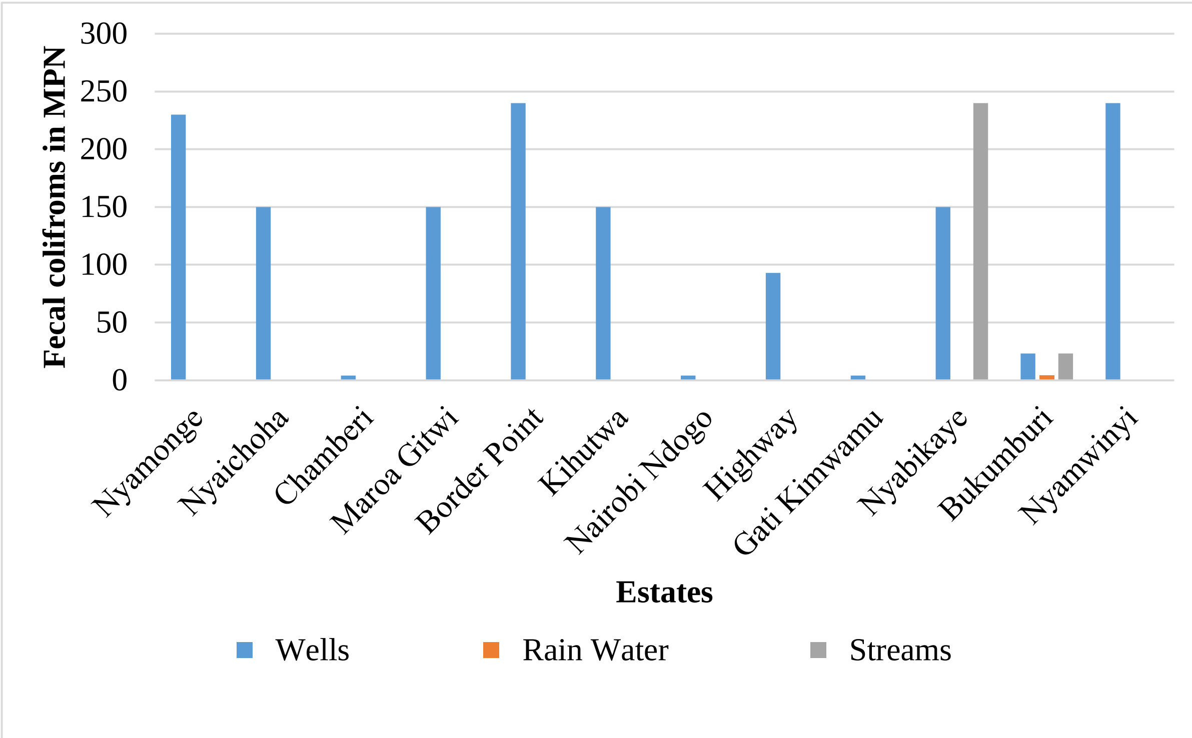


Figure 4.5.2: Fecal coliform in MPN in drinking water from selected sources.

Samples from 56% of the sources studied did not conform to quality standards of nil fecal coliform. It was inferred that water from these sources had a recent fecal contamination and possessed risks of microbe pathogens and that the sources are prone to seepage from pit latrines and to biological waste disposals.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The sources of drinking water for the residents in Kuria west, Migori County are wells 83%, streams 8% and rainwater harvest 7%. Water samples from 15% of the sources studied had an average pH value of 5.3 which is below limit of 5.5 for quality standards and inferred that they are polluted.

Water samples from 26% of the sources studied had nitrites of 0.008 mg/L and 15% had nitrates of 104.65 mg/L. These concentrations were above the limit of 0.003 mg/L and 45 mg/L respectively for quality standards. It was inferred that the sources are polluted with nitrites and nitrates.

Water samples from 3% of the sources studied had chromium of 0.08 mg/L against limit of 0.05 mg/L, 7% had manganese of 0.7 mg/L against limit of 0.1 mg/L, and 7% had lead of 0.04 mg/L against limit of 0.01mg/L standards for drinking water. It was inferred that the sources are polluted with the above heavy metals.

Water samples from 78% of the sources studied had total coliforms of 136 MPN and that 56% had fecal coliform of 120 MPN. Quality requirement is nil for both total and fecal coliforms, it was inferred that these sources are contaminated with microbes.

Water samples from 82% of the sources studied were unsuitable for human consumption. This implies that majority of Kuria West residents consume poor quality water according to standard guidelines.

5.2 Recommendations

To ensure that the residents of Kuria West have access to quality drinking in line with the constitutional provisions, the study made the following recommendations:

1. The individual residents of Kuria West should employ appropriate point of use water treatment systems for wells and rainwater harvests in their respective home.
2. The County Government of Migori to come up with point of source water treatment systems for Bukumburi, Nyabikaye and Gati Kimwamu streams.
3. The selected drinking water sources should be protected to eliminate pollution.

The study also recommended that future research should focus on:

1. Identifying health challenges on the residents of Kuria West associated with consumption of water from the selected sources.
2. Determining the sustainable drinking water treatment plant for the main water sources.

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APPENDICES

Appendix 1 : Questionnaire

To be completed by Heads of Households

Name of Village…………………………………………………………… (Optional)

1.0 Personal Details

1.1 State your gender

Male	Female

1.2 State your Age bracket (Years)

Below 40	41-50	51-59	Above 60

1.3 State your highest level of education

Primary	Secondary	Tertiary	Graduate	Post Graduate

1.4 State how long you have lived at Kuria West

Below 5	5-10	10-15	Above 15

1.5 State the size of your household

Below 5	5	Above 5

1.6 State your daily drinking water requirement in litres?

Below 50	50-100	100-150	Above 150

2.0 Domestic Water Resources

2.1 State your main source of drinking water?

Well	Rainwater Harvest	Streams	Others