Assessment of Bacteriological and Physico-Chemical Quality of Water for Domestic uses in Kiamumbi Catchment, Kiambu County Kenya.

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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This thesis has been submitted for examination with our approval as the university supervisors.

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DEDICATION

This work is dedicated to my Uncle, who laid a foundation for me to pursue my education. To my parents who have always stood with me in prayers and who taught me that with perseverance, humility and honesty I can achieve a lot.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectroscopy
APHA	American Public Health Association
EC	Electrical Conductivity
KEBS	Kenya bureau of Standards
KMCSL	Kiamumbi Water Multi-Purpose Cooperative Society
KWT	Kiamumbi Water Trust
IWRM	Integrated Water Resources Management
MPN	Most Probable Count
RS 1	River Sampling point one
RS 2	River Sampling point two
RS 3	River Sampling point three
RSTD	Recommended Standard
RSV	Reservoir
SF	Storage facility
TDS	Total Dissolved Solids
UNEP	United Nations Environment Programme
WHO	World Health Organization

ABSTRACT

Water quality is determined by the bacteriological and Physico-chemical parameters. The water quality of Kiamumbi Reservoir water project is of great importance because it is used for consumption in Kiamumbi Estate. This study aimed at analyzing the bacteriological and physico-chemical quality of water in Kiamumbi catchment and water supplied to households during the wet and dry seasons. Portable pH meter (Jenways), Portable TDS meter 4076 (Jenways), Portable Ec meter (Jenways), and Portable turbidity meter were used after calibration to measure pH, total dissolved solids, electrical conductivity and turbidity respectively. The highest mean pH was 7.24±0.06 recorded at the first sampling point of the feeder river. The highest level of Total dissolved solids was 217.3±21.5 at the storage facility during wet season while for turbidity was 20.5±0.85 NTU recorded at the second sampling point of the feeder river during the wet season. The highest level of electrical conductivity was 0.25±0.02µS recorded at the first sampling point of the feeder river. Heavy metals were analyzed using atomic absorption spectroscopy. The metals that were found to have concentrations above the acceptable levels were Cadmium, Chromium, Lead, Iron and Nickel. The highest mean concentration of Cadmium was 0.04 ±0.007mg/L recorded at the first sampling point of the river during the wet season. The highest mean concentration of chromium was 0.94±0.004 mg/L recorded at the reservoir during the dry season. Lead was highly concentrated during the wet season at 1.3 ±0.83 mg/L at the second sampling point of the feeder river. The highest mean concentration of iron was 0.72 ±0.18 mg/L at the first sampling point of the feeder river. The highest mean concentration of Nickel was 0.47 ±0.18 mg/L recorded at the storage facility during the dry season. The bacteriological quality of water was analyzed using the standard method for analysis of water. During the dry season, *salmonella typha, pseudomonous aeruginosa, Shigella dysentriae* and *streptococcus* were found in the river. During the wet season *Citrobacter freundii, enterobacter aerogenes, Klebssiella oxycota, Proteus vulgaris* and *dysentriae* were found to be present in the same river. *Escherichia coli, pseudomonous aeruginosa, Shigella dysentriae, Streptococcus* and *Enterobacter aerogenes* were found in the reservoir during the dry season. *Escherichia coli, Citrobacter freundii, Salmonella, Shigella dysentriae, Klebssiella oxycota*, and *Enterobacter aerogenes* were found to be present in the reservoir during the wet season. Qualitative data analysis showed that the main activities contributing to pollution were horticultural farming (96 %), Livestock keeping (71%), poultry keeping (25%), Coffee plantations (39 %), construction (36 %) and quarrying (61 %) while the sources of pollutants were found to be sewage (82 %), animal waste (71 %), fertilizers (79%), insecticides and pesticides (57%), surface run-off (79 %), construction waste (18 %) and domestic waste (4 %). The results of this study indicated that the catchment is polluted by pollutants from different sources. However, after treatment, the bacteriological quality of water was found to be within acceptable levels but the treatment method was found to be ineffective in reduction of chemical pollutants. It is for this reason that this study concluded that the water distributed to households in Kiamumbi estate is not fit for drinking and therefore a more effective treatment method should be put in place.

CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND INFORMATION

Water resources are of critical importance to both natural ecosystem and human development. Water quality concept can be defined as a conventional ensemble of physical, chemical and biological parameters, formed in a certain category, which expresses the possibility of its anthropogenic usage to meet a certain purpose such as potable, agricultural, recreational and industrial water usages (Sargaonkar et. al, 2003).

The healthy aquatic ecosystem is dependent on the physico – chemical and biological characteristics (Venkatesharaju et al, 2010). To assess these characteristics, monitoring of these parameters is essential to identify magnitude and source of any pollution load. These characteristics can identify certain condition for the ecology of living organisms and suggest appropriate conservation and management strategies (Damotharan et al, 2010; Prasanna and Ranjan, 2010)

Contamination of water bodies has increasingly become an issue of serious environmental concern. Contaminants such as bacteria, heavy metals, nitrates and salts have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, agricultural activities, industrial discharges and over-use of limited water resources (Singh et al, 2003).

The problem of water pollution and quality degradation in the developing countries is increasingly becoming a threat to the natural water resources. This phenomenon is attributed to the increasing quest of these countries to attain industrialization status and diversification of the national development goals and Kenya is no exception to this phenomenon (Kithiia, et al 2011).

Kenya is described as a water scarce country, and yet future projections show that per capita available water currently at $650m^3$ /year, will likely drop to $359m^3$ /year by 2020, as a result of population growth. This figure is far much below the global accepted value of $1000m^3$ per capita level. Urgent action is therefore needed to increase the capacity of the water sector to improve the availability and accessibility of clean and safe drinking water (GoK, 2007).

Surface and ground water resources in Kenya are increasingly becoming polluted. Water pollution occurs when pollutants are discharged directly or indirectly into water bodies leading to degradation. Continued consumption of polluted water may lead to serious impacts on human health. Water quality in reservoirs is an important aspect of water resources management. It is a key catalyst for development and conservation because it determines the spatial- temporal dynamics of aquatic organisms and drives various water uses in aquatic ecosystems including reservoirs.

Reservoir water is rarely pure since it contains different kinds of dissolved and particulate matter including gases and solids. It is from this background that analysis of the quality of water in Kiamumbi catchment was deemed necessary. This water is collected from the reservoir for treatment by Kiamumbi Water Trust and supplied to approximately 850 households in Kiamumbi Estate in Kiambu county for domestic use. Water for domestic use and especially for drinking should meet the set standards by World Health Organization (WHO). Therefore, based on these facts, investigating the water quality of Kiamumbi catchment to understand the pollutants therein, and to find out if these pollutants are reduced to acceptable levels after treatment for domestic use, was the main purpose of this study.

Economic and demographic growth in agricultural water sheds often leads to intensive land use and increased generation of point and non-point source pollutants. These pollutants, which include pathogens, nutrients, toxic contaminants and sediments, are then transported by run-off to water bodies causing serious environmental effects. Rampant construction of residential homes and increased farming activities along the catchment areas has been taking place hence also the need for this study to find out the effects of increased population growth and extensive agriculture.

1.1 Kiamumbi Water Trust

Kiamumbi water Trust (KWT) is a subsidiary of Kiamumbi Multi-purpose Cooperative Society Limited (KMCSL). KMCSL was formed and registered in the early 1970’s and the Society’s core business was coffee farming on a 740-acre piece of land located 15 Kilometers from Nairobi Capital city. To meet the high irrigation water requirements of coffee, KMCSL invested in the construction of a reservoir at a cost of Kshs 6.5. Million, resting on approximately 26 acres of land (KWT, 2014).

In the Mid 1980's coffee prices declined significantly prompting the KMCSL shareholders to do away with approximately 50% coffee farming. The resultant vacant land was subdivided into residential plots and consequently allotted to the shareholders in 1985. In the early 1990s coffee prices continued to decline and KMCSL shareholders resolved to wind up the coffee farming business, and in addition allotted the resultant land to the 661 KMCSL shareholders in the year 1994. This resulted in widespread buying and selling of residential plots from the year 1994 and hence rapid development of Kiamumbi Estate.

Development of Kiamumbi Estate led to a high water demand and with the reservoir resource lying idle, this made KMCSL invest Kshs 0.5 Million in developing a piped water supply project design report. With the reservoir as the source, this placed the total project's implementation cost at Kshs 22 Million. In the year 2006, KMCSL applied for financing by K-rep Bank under the World Bank funded Output Based Aid (OBA) program now renamed to Maji ni Maisha program. Under this program the maximum funding/loan amount that was available for projects was Kshs 10 Million, and with KWT's implementation budgeted at Kshs 22 Million, this led to phasing of the Project's design into two phases (1 & 2) (KWT, 2014).

KWT qualified for Maji Ni Maisha loan and was awarded Kshs 10 million towards the implementation of Phase 1, with KMCSL contributing Kshs 4 Million towards the same. Construction works kicked off in 2008 and were completed in July 2009. In August 2009, KWT became operational. The reservoir is currently utilized by residents of Kiamumbi Estate as a source of water for their domestic use through the Kiamumbi Reservoir Water Project (KWT, 2014).

1.2. Statement of the Problem

Water pollution occurs when pollutants are discharged directly or indirectly into water bodies leading to degradation. The availability of good quality water is an indispensable feature for preventing diseases and quality of life. There are extensive anthropogenic activities along Kiamumbi catchment which can contribute to pollution of the catchment. In addition natural geophysical processes are known to pollute water bodies and the catchment is no exception. There are many people who fetch water from the river for domestic use and homegrown treatment methods if any may not make the water safe for human consumption. There are others who graze their livestock along the river and around the reservoir and they also water the livestock directly in the two water bodies. This poses serious threat in relation to microbial pollution of water. KWT abstracts water from the reservoir for pre-treatment followed by supply to residents of Kiamumbi estate. Consumption of water obtained directly from the water bodies without treatment and if the water is not treated to meet acceptable standards for water for domestic use, this poses serious health impacts to unsuspecting consumers.

1.3. Objectives

1.3.1. Main Objective

To investigate the quality of water for domestic use in Kiamumbi Catchment.

1.3.2. Specific Objectives

1. To determine the physico - chemical quality of water in the feeder river, reservoir and the

   storage facility.

2. To determine the Bacteriological quality of water in the feeder river, reservoir and the storage facility.

3. To assess the community awareness on water pollution in Kiamumbi Water catchment.

1.4. Hypothesis

Kiamumbi reservoir is not polluted through the feeder river during the wet season than dry season.

1.5. Research Questions

Several research questions motivated this study. In order to achieve the set objectives, these research questions were answered and aided in testing the hypothesis. These questions are;

1. How does pollution of Kiamumbi Reservoir compare to pollution of the Feeder River?

2. What are the main pollutants present in Kiamumbi Catchment?

3. What are the possible causes of pollution in Kiamumbi Catchment?

4. During which season is the catchment highly polluted?
5. How effective is the water treatment method applied in Kiamumbi reservoir water project?

1.6. Significance of the Study

This study was intended to provide useful information on the quality of water in Kiamumbi catchment. The information was important in determining whether the water was fit for human consumption after treatment. This study also helped in identification of specific pollutants present in the water and established of the possible sources of the pollutants. The study was important for evaluation of the effectiveness of the treatment method used to treat this water. The study results will guide improvement of the treatment works in the basin.

1.7. Justification

Kiamumbi catchment supplies water to over 800 households feeding on average 5000 persons. Surface water are prone to pollution hence the need to establish the levels of pollution in Kiamumbi catchment. Continued consumption of contaminated water may have adverse human health impacts hence the need for early warning. This study was aimed at establishment of the effectiveness of the treatment method applied by Kiamumbi Water Trust and recommend improvement if there are pollutants found to be present after treatment.

1.8. Conceptual Framework

A conceptual framework was developed to link pollution to relevant independent variables. Pollution of the catchment is dependent on the different pollutants from different sources.

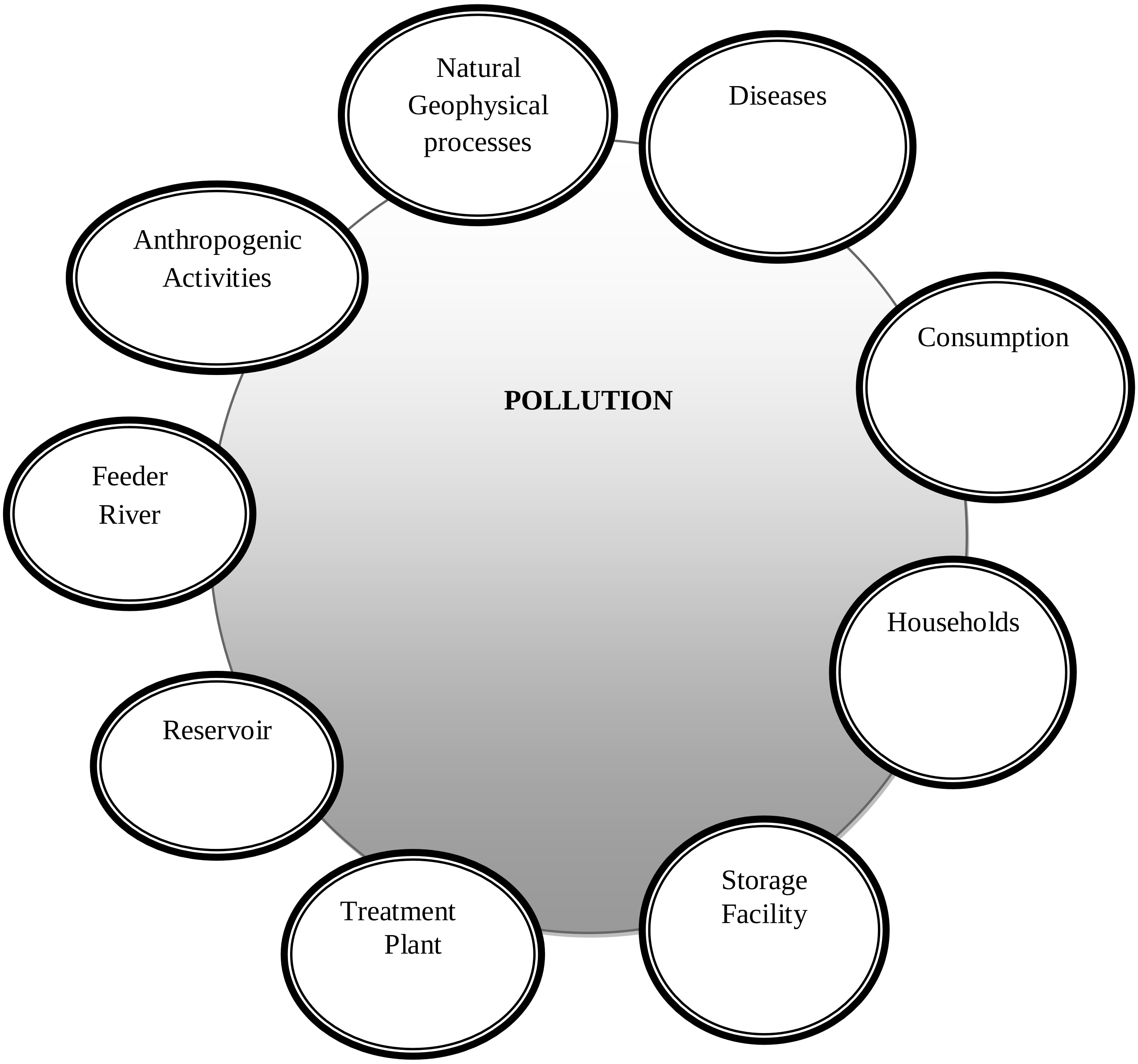


Figure 1.1: Conceptual Framework

In the conceptual framework depicted in figure 1.1, water bodies that were involved in this study which are the feeder river and Kiamumbi reservoir were hypothesized to be polluted from pollutants resulting from both human activities and natural geo-chemical processes. The pollutants may be in the form of heavy metals, ions, physical pollutants and micro-organisms. The feeder river drains into the reservoir and some pollutants may be deposited in the reservoir by the feeder river or some pollutants may find their way into the reservoir directly for example through run-off or natural activities like weathering of rocks and decay of organic materials like plant remains in the reservoir.

The water is abstracted from the reservoir to a treatment plant. At the treatment plant, the intention is to remove present pollutants and make the water fit for human consumption. After treatment the water is pumped into a storage facility and then distributed to households in Kiamumbi Estate for consumption. During distribution, the treated water can be polluted if there are broken pipes or corrosion. It is important to note that some community members fetch the water directly for consumption from the river and the reservoir without any treatment. This poses serious threat of infection with water borne diseases.

The water is distributed to the house holds for domestic use including consumption. If the treatment method is not effective to reduce different pollutants to acceptable levels, consumption of this water by local community poses a serious community health concern. This is because toxic substances and pathogens may be ingested and accumulate in human biological systems leading to diseases. Therefore, to ensure good quality of drinking water, treatment should be effective and also ensure sources of pollutants that enter the water bodies are identified and measures taken to prevent or control pollution.

CHAPTER TWO

LITERATURE REVIEW

2.0. General Overview

The water we drink is an essential ingredient for our wellbeing and a healthy life. Drinking water is potable water intended for human consumption (KEBS, 2007). The World Health Organization (WHO) states that one sixth of the world's population; approximately 1.1 billion people do not have access to safe water and 2.4 billion lack basic sanitation (EPHA, 2009). The World Health Organization estimated that about 80% of ill-health especially in developing countries are water related (Cheesbrough, 2000).

Estimations indicates that more than fifty countries of the world with an area of 20 million hectares are treated with polluted or partially treated polluted water and this poor quality water causes health hazard and death of human being, aquatic life and also disturbs the production of different crops (Ashraf et al, 2010). In fact, the effects of water pollution are said to be the leading cause of death for humans across the globe, moreover, water pollution affects our oceans, lakes, rivers and drinking water, making it a wide spread and global concern (Scipeeps, 2009).

Africa faces huge challenges with multiple issues that adversely affect public health. One major challenge is the ability for both rural and urban Africans to have access to clean water supply. According to the WHO (2006), only 50% of the world's population had access to adequate sanitation systems and efforts to achieve the millennium Development Goal, which is aiming for 75% by the year 2015, will fall short by nearly half a billion people. There are limited sources of water available to provide clean drinking water to the entire population of Africa. Surface water sources are often highly polluted, and infrastructure to pipe water from fresh, clean sources to arid area is too costly of an endeavor (Awuah, et al, 2009).

The problem of water pollution and quality degradation in the developing countries is increasingly becoming a threat to the natural water resources. This phenomenon is attributed to the increasing quest of these countries to attain industrialization status and diversification of the national development goals and Kenya is no exception to this phenomenon (Kithiia and Khroda, 2011).

Water quality characteristic of aquatic environment arise from a multitude of physical, chemical and biological interactions. A regular monitoring of water bodies with required number of parameters in relation to water quality prevents the outbreak of diseases and occurrence of hazards (Arrigo, 2011).

2.1. Water Pollution

In recent times, environmentalists have become increasingly concerned about the pollution of surface waters. The WHO estimated that about 80% of ill health especially in developing countries are water related (Cheesbrough, 2000).

Some water pollution effects are recognized immediately, whereas others do not show up for months or years (Ashraf et al, 2010). Rivers are vital and vulnerable freshwater ecosystems that are critical for the sustenance of all life. However, the declining water quality of these ecological systems threatens their sustainability and is therefore a matter of serious concern. Rivers are water ways of strategy importance across the world, providing main water resources for domestic, industrial and agricultural purposes (Jain, 2009).Untreated discharge of pollutants to a water resource system from domestic sewers, storm water discharges, industrial waste waters, agricultural run-off and other sources, all can have short term and long term significant effects on the quality of a river system. It is a common practice for the people living along a river catchment to discharge their domestic waste as well as human excreta into rivers. Wild and domestic animals using same drinking water can also contaminate the water through direct defecation and urination (Jain, 2009).

The quality of a stream or a river is often a good indication of the way of life within a community through which it flows. It is an indicator of the socio-economic conditions and environmental awareness and attitude of its users. Everything that happens in a catchment area is reflected in the quality of the water that flows through it, because the result of human activity and lifestyle ultimately end up in rivers, through run-off (The water wise education team, 2013).

2.2. Chemical Quality

Chemicals enter the water supply from natural and anthropogenic sources. These contaminants reach drinking water supplies from various sources, including municipal and industrial discharges, urban and rural runoff, natural geological formations, drinking water distribution materials and the drinking water treatment process. Chemical contaminants for which epidemiologic studies have reported associations include the following: aluminium, arsenic, disinfection by-products, fluoride, lead, pesticides and radon. Health effects reported have included various cancers, adverse reproductive outcomes, cardiovascular disease and neurological disease (Robert H.F, 2012).

The health concerns associated with chemical constituents of drinking water differ from those associated with microbial contamination and arise primarily from the ability of chemical constituents to cause adverse health effects after prolonged periods of exposure. Guideline values are derived for many chemical constituents of drinking water. A guideline value normally represents the concentration of a constituent that does not result in any significant risk to health over a lifetime of consumption (WHO, 2011).

2.3. Microbial Quality

Bacteriological pollution in water is caused by the excreta of warm blooded animals including man, domestic and wild animals, and birds by a wide variety of genera. The main ones are Coliform group and certain subgroups, Faecal streptococci and certain sub-groups, and miscellaneous organisms. These cause disease as dysentery, typhoid fever, para-typhoid fever, cholera and gastroenteritis. Pollution is also brought about by alga, diatoms and small animals like protozoa, rotifers and crustaceans (Varshney, 2008). For microbial quality, verification is based on the analysis of faecal indicator micro-organisms, with the organism of choice being Escherichia coli or thermotolerant coliforms. Escherichia coli provide conclusive evidence of recent faecal pollution and should not be present in drinking water (WHO, 2011).

2.3.1. Total Coliform Bacteria

These include a wide range of aerobic and facultatively anaerobic, gram-negative, non-spore-forming bacilli, capable of growing in the presence of relatively high concentrations of bile salts with the fermentation of lactose and production of acid or aldehyde within 24hours at 35 - 37ºc. *Escherichia Coli* and thermotolerant coliforms are a subset of the total coliform group that can ferment lactose at higher temperatures. Total coliform bacteria (excluding E. coli) occur in both sewage and natural waters. Some of these bacteria are excreted in the faeces of humans and animals, but many coliforms are heterotrophic and are able to multiply in water and soil environments (WHO, 2011).

Total coliforms can also survive and grow in water distribution systems, particularly in the presence of biofilms. Total coliforms should be absent immediately after disinfection, and the presence of these organisms indicates inadequate treatment. The presence of Total coliforms in distribution systems and stored water supplies can reveal re-growth and possible biofilm formation or contamination through ingress of foreign materials. Total coliform bacteria that are able to ferment lactose at 44 - 45ºc are known as thermotolerant coliforms. In most waters, the predominant genus is *Escherichia,* but some types of *citrobacter, Klebsiella* and *Enterobacter* are also thermotolerant. *Escherichia coli* is present in very high numbers in human and animal faeces and is rarely found in the absence of faecal pollution, although there is some evidence for growth in tropical soils (WHO, 2011).

2.4. Sources of Water Pollution

Pollution of water resources can be caused by atmospheric dissolved gases, weathering soil and rock minerals, decomposition of animal and vegetable materials and industrial effluents, sewage and municipal wastes. Since surface water is exposed directly to atmosphere as well as connected with several minor inlets as rivulets, seasonal streams and surface drains, there is continuous exchange of dissolved and atmospheric gases and addition of waste materials through the conveyances. The main sources of surface water pollution are atmospheric gases, Surface water run-off, decomposition products of animals and plant materials, industrial and municipal waste (Varshney, 2008)

The quality of water in catchment waterways is threatened by both point sources and non-point (diffuse) sources (NPS) of pollutants (Bhaduri et al). Point source pollutants originate from identifiable discharge points, including irrigation drainage water, urban effluents and storm water drains, industrial effluents, and intensive animal operations. Management of point sources is generally easier than for non-point sources, as effluent controls can be placed on the quantity and quality of the polluted water. Non-point source pollution refers to pollutants that cannot be readily identified as originating from one discrete location or point (Hassan, 2006).

Diffuse source pollutants are typically carried to receiving water bodies by precipitation and subsequent land drainage or run-off. Examples include feacal coliform bacteria, heavy metals, and oil and grease that enter a receiving water body in the run-off from urban streets or fertilizers and animal wastes that drain into surface waters from agricultural lands (Jamieson et al, 2004).

Almost all water in its natural state is impure, because of common naturally occurring and anthropogenic sources of pollution. Naturally occurring sources of pollution arise from the diversity of aquatic animals and plants that inhabit the bodies of water used eventually for human consumption. In addition to microbial organisms that live in water, fish, aquatic animals and wildlife produce wastes that contaminate the water. Soils in contact with the water also harbor microorganisms. Decaying tree leaves and branches contribute organic materials. Natural rock and soil formations may introduce radionuclides, nitrogen compounds, and heavy metals such as arsenic, cadmium, chromium, lead and selenium as well as other chemicals. Run-off from urban streets is a growing contributor to water pollution, especially after periods of heavy rainfall. Pet wastes that washed into storm drains can represent a hazard to human and animal health (Robert, 2012).

2.4.1. Agricultural Sources

Water is a precious natural resource on which rely the sustainability of agriculture and the civilization of mankind. Unfortunately, it has been subjected to maximum exploitation and severely degraded or polluted due to anthropogenic activities. The pollution includes point sources such as emission, effluents and solid discharge from industries, vehicle exhaustion and metals from smelting and mining, and nonpoint sources such as soluble salts (natural and artificial), use of insecticides/pesticides, disposal of industrial and municipal wastes in agriculture, and excessive use of fertilizers (McGrath et al, 2001).

Wastes from agricultural operations, which are usually discharged into surface waters have been reported to have serious environmental and human health concerns (Adams and Kolo, 2006). High concentration of bacteria and nitrates discharged into water can occur from animal husbandry operations like grazing and that this can result in health hazards to man due to the presence of pathogens (Atiribom et al, 2006). Wastes from Agricultural operations which are usually discharged into surface waters have been reported to have serious environmental and human concerns (Adams and Kolo, 2006).

2.4.2. Heavy Metals

Land and water pollution by heavy metals is a worldwide issue. All countries have been affected, though the area and severity of pollution vary enormously (McGrath et al., 2001). Heavy metals like copper, Zinc, Manganese, Iron, Cadmium, Chromium, Lead among others are usually present in water at low concentration, but enhanced concentrations of these metals have found as a result of human activities. Investigations have been made in different countries by different researchers on the extent of heavy metals pollution in surface water (Zakir et al 2011).

The main sources of lead contamination of the aquatic environment are the industrial discharges from smelters, battery manufacturing units, run off from contaminated land areas, atmospheric fallout and sewage effluents. Of the atmospheric sources, combustion of Lead produces maximum release of lead into the air, which results in higher lead levels in urban air as well as roadsides. Lead inhibits the function of certain enzymes necessary for the formation in bone marrow haem, the pigment that combines with protein to form haemoglobin. Lead also replaces calcium in the bone. Lead poisoning in children can produce brain damage (Varshney, 2008).

Chromium is widely used in a variety of industries like electroplating, tanning, manufacture of paints and pigments and fungicides (WHO, 2011). Chromium is toxic in high concentrations to both plants and animals. It is reported to cause perforations, bronchiogenic carcinoma in continuously exposed humans (Varshney, 2008).

Copper mining and metallurgical operations contribute to contaminations of aquatic environments. Copper salts are used as fungicides and algicides. Bordeaux mixture, a formulation of copper sulphate and calcium carbonate is still used as a fungicide. Copper is toxic to many aquatic plants at low levels (Varshney, 2008).

2.4.3. Domestic and Industrial Sources

The quality of water is deteriorated on the addition of used water having chemical constituents of undesirable concentrations. In cities contaminated water after bath, kitchen wash, washings and a large volume of raw sewage discharged into the main stream pollutes water to a greater extent. Similarly, discharge of municipal wastes, industrial effluents and waste byproducts of varying characteristics aggravate the water quality. Near the cities, the surface water resources as rivers, ponds and lakes where effluents are discharged from municipal and industrial wastes, are highly polluted (Varshney, 2008).

2.4.4. Weathering of rocks, Minerals and Soils

All natural waters containing soluble inorganic ions are mainly from the weathering of soil and rock minerals. The weathering products of the rock minerals are released and transported by the action of water. Hence the nature and concentration of an ion in water depends upon the nature of rock minerals, its solubility and weatherability in fresh water or carbonated water, climate and local topography. The main rock minerals forming the earth's surface are oxides of silicon(quartz), aluminium(gibbsite), iron(huntite, limonite,magnetite), titanium(rutile) and of sulphides (chlorite, pyrite), sulphates(gypsum,barite), carbonates (calate, magnesite, dolomite), hydroxide (brucite), phosphates(apatites) and two –layer (kaolinite), three –layer (montmorillonite, illite, vermiculite) and interstratified clays (Varshney, 2008). In natural waters, solubility of minerals is influenced by pH particularly of iron and manganese hydroxides which decreases and that of alluminium hydroxide which increases with the increase in pH. Generally, the phosphate concentration in natural waters is low but high values can be obtained on addition of phosphate bearing industrial effluents.

Large quantities of soluble salts, and particularly the nutrients are released from the upper soil surface by run-off. These nutrients may be released either from the soil, plant residues or from the added fertilizers. The water is the main carrier of these nutrients by surface or sub-surface drainage. But in conditions of high rainfall, both in quantity and intensity, soil particles are dispersed by rain drops, and carried away into bigger streams by surface run-off. Sometimes all the top soil is eroded away and deposited either on the way or finally in the estuaries (Varshney, 2008).

2.4.5. Atmospheric gases

When the concentration of dissolved gases like nitrogen, sulphur dioxide, hydrogen sulphide, carbon monoxide, hydrogen and ammonia increases sufficiently in the atmosphere, it subsequently enhances their content in water of their contact. However, the actual concentration of these gases in water depends upon their concentration in the atmosphere and their solubility and diffusivity in water, temperature and viscosity of the water. Generally, surface waters near the cities and industrial complexes where atmosphere is more polluted by factory smoke and discharge of burnt fuel from the vehicles are more polluted than those of rural areas. Moreover stagnant waters like those in lakes and ponds are more polluted than flowing waters (Varshney, 2008). Atmospheric emissions, mainly those containing sulphur and nitrogen oxides from fossil-fuel combustion, are the primary cause of acid rain and, consequently, acidified fresh water. Once in the atmosphere, sulphur and nitrogen are oxidized and then react with atmospheric moisture to form acids. They are then returned to Earth through wet (rain, mist, fog, snow) or dry deposition, gradually decreasing the pH of water (UNEP, 1991).

2.5. Physical Water Quality Indicators

2.5.1. pH

The pH of water is a measure of the hydrogen ions concentration in water and, in most natural waters is controlled by the carbon dioxide-bicarbonate equilibrium system. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. For effective disinfection with chlorine, the pH should preferably be less than 8; however, lower - pH water is more likely to be corrosive. The pH of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems. Extreme values of pH can result from accidental spills, treatment breakdowns, and insufficiently cured cement mortar pipe linings or cement mortar linings applied when the alkalinity of the water is low. (WHO, 2011).

2.5.2. Electrical conductivity (EC).

Electrical conductivity is measured in Siemens. It is a measure of the capacity of water to conduct electrical current and it is directly related to the concentration of salts dissolved in water, and therefore to the total dissolved solid (CWT, 2004).

2.5.3. Total dissolved solids

TDS is the term used to describe the inorganic salts, and small amounts of organic matter present in solution of water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, chloride, sulphate and nitrate anions. TDS in water supplies originate from natural sources, sewage, urban and agricultural run-off, and industrial waste water. (WHO, 2004). The palatability of water with a TDS level of about 600 mg/L is generally considered to be good. Drinking – water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/L (WHO, 2011).

2.5.4. Turbidity

Turbidity in water is caused by suspended particles or colloidal matter that obstructs light transmission through the water. Micro-organisms are typically attached to particles, and removal of turbidity by filtration will significantly reduce microbial contamination in treated water (WHO, 2011).

2.6. Treatment for Water Supplies

Treatment performance varies according to local conditions and circumstances. The ability to achieve a guideline value within a drinking – water supply depends on a number of factors including;

i. The concentration of the chemical in raw water.

ii. Control measures employed throughout the drinking – water system.

iii. Nature of the raw water (ground water or surface water, presence of natural organic matter and inorganic solutes and other components, such as turbidity.

iv. Treatment process already in place.

If guideline value cannot be met with the existing system, then additional treatment may need to be considered, or water might need to be obtained from alternative source (WHO, 2011)

After untreated water flows from storage area into the treatment plant, it first undergoes coagulation to remove suspended material. Aluminium sulphate is used as the coagulating agent. After the coagulating agent has been mixed with the water, the mixture is transferred to sedimentation tanks. The water then is filtered to remove smaller impurities. Subsequently, the water is treated with a disinfectant such as chlorine to destroy pathogens (Robert H.F, 2012).

2.7. Legal Framework

2.7.1. The water Act, 2005

The water Act provides for the control of water pollution in Part V section 81. Section 81 states that “No person shall discharge or apply any poisonous, toxic, noxious or obstructing matter, radioactive waste or other pollutants or permit any person to dump or discharge such matter into any water resource unless the discharge of such poisonous, toxic, noxious or obstructing matter, radioactive waste or pollutants has been treated to permissible standards authorized by the Authority (GOK, 2002)

2.7.2. Environmental Management and Coordination (Water Quality) Regulations 2006

The regulation in part II provides for the protection of water resources. Regulation 4(1) states that “Every person shall refrain from any act which directly or indirectly causes, or may cause immediate or subsequent water pollution, and it shall be immaterial whether or not the water resource was polluted before the enactment of the Act”(GOK, 2006). Regulation 4 (2) states that “No person shall throw or cause to flow into or near a water resource any liquid, solid or gaseous substance or deposit any such substance in or near it, as to cause pollution"(GOK, 2006).

The First and second Schedule of Water Quality Regulations,2006 sets out standards for sources of domestic water.

Table 2. 1: First Schedule, Quality Standards for Sources of Domestic Water

Parameter	**Guide Value (Maximum allowable)**
pH	6.5 – 8.5
Suspended Solids	30 (mg/L)
Nitrate –NO_3	10 (mg/L)
Ammonia – NH_3	10 (mg/L)
Nitrite – NO_2	3 (mg/L)
Total Dissolved Solids	1200 (mg/L)
E. coli	Nil/100ml
Fluoride	1.5 (mg/L)
Phenols	Nil (mg/L)
Arsenic	0.01 (mg/L)
Cadmium	0.01 ((mg/L)
Lead	0.05 (mg/L)
Selenium	0.01 (mg/L)
Copper	0.05 (mg/L)
Zinc	1.5 (mg/L)
Alkyl benzyl sulphonates	0.5 (mg/L)
Permanganate value (PV)	1.0 (mg/L)

Source; Environmental Management and Coordination (Water Quality) Regulations 2006

Regulation 6 provides for protection of Protection of Lakes, Rivers, Streams, Springs, Wells and other water sources. Regulation 6 © states that “No person shall cultivate or undertake any development activity within a minimum of six meters and a maximum of thirty meters from the highest ever recorded flood level, on either side of a river or stream, and as may be determined by the Authority from time to time (GOK,2006).

CHAPTER THREE

THE METHODOLOGY

This chapter describes the experiment design, Area of Study, Target population, sample size determination, water sampling procedure, data collection technique, data analysis and presentation that were used in the study.

3.0. Experiment Design

Quantitative research design was used to establish the physical and chemical quality of water. Triplicate samples were collected from eight sampling points were collected during the wet season in the month of June and during the dry season in the Month of September. The samples were randomly collected along the feeder river from the three sampling points at an interval of 2 km upstream from the reservoir denoted as river sampling point one (RS1), river sampling point two (RS2) and River Sampling point three (RS3). Plate 3.1., represents a section of the feeder river. For bacteriological quality analysis, the samples were collected on sterilized sampling bottles from the eight sampling points. The samples were delivered in the laboratory within four hours.

Three samples from each of the Four (4) sampling points were collected in the Reservoir denoted as 'RSV' giving a total of twelve (12) samples. Three samples were randomly collected from the storage facility denoted as 'SF'. A total of fourty eight samples were collected. The samples were analysed and the results were subjected to extensive statistical analysis for hypothesis testing.. Qualitative research design was also used using questionnaires for collection of qualitative data which was organized and analyzed using quantitative analysis.

Plate 3. 1: Section of Feeder River

Plate 3.1 above shows section of the feeder river that drains into Kiamumbi reservoir.

Plate 3. 2: Kiamumbi Reservoir

Plate 3.2 illustrates part of the reservoir. It also shows the existence of residential houses and it is from such households that anthropogenic activities with potential to pollute the reservoir take place.

Plate 3. 3: Storage Facility

Plate 3.3 above shows the storage facility in which water is stored after treatment for supply to consumers in Kiamumbi estate.

3.1. Area of Study

The area of study was as presented in figure 1.2.

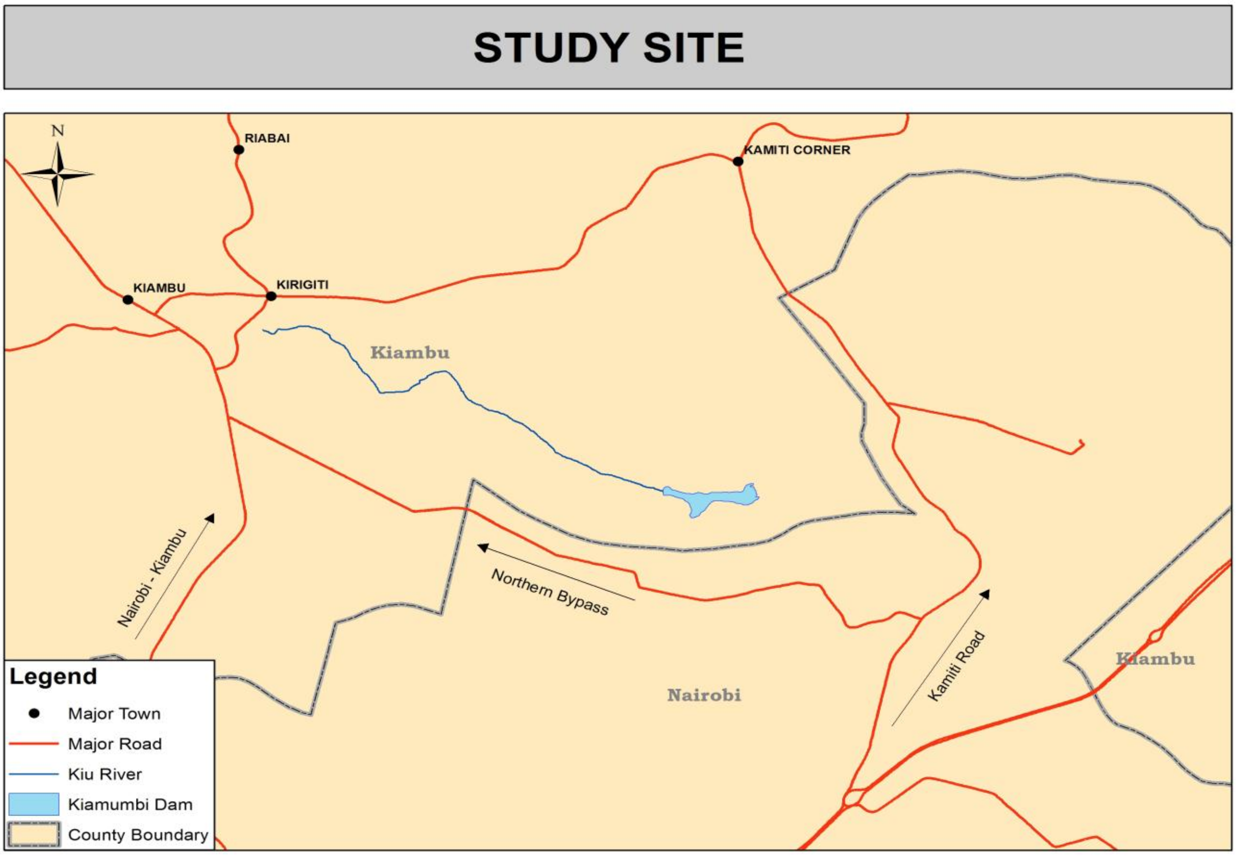


Figure 1. 2: Map showing area of study

The research was carried out in Kiamumbi catchment area in Kiambu county. Kiambu county has a total area of 1,448 km. It boarders Nairobi County to the south, Murang'a county to the north Nakuru to the West and Machakos county to the East. The study aimed at analysis of water in Kiamumbi reservoir, the feeder river and the storage facility. The reservoir is Located about 15 Km North of the capital city, Nairobi and about 4 Km from the Kamiti Maximum Prison. The geographical position of the reservoir is 1^{o} 10^{1} 40^{11}S, $36^{o}53^{1}3^{11}$E.

3.1.1. Climate.

The climate in Kiambu county is largely influenced by altitude. Annual rainfall ranges from 750 mm in the lower region to over 1,300 mm in the upper regions. Rainfall is bimodal. Long rains occur between April and May, followed by a cool season during July and August, culminating in short rains between October and November. Rainfall distribution is reliable and has largely influenced agricultural activities in the County. Temperatures range from 20.4^{o} C in March/April to 12.5^{o}C in July/August in the upland zone.

3.1.2. Land Use

Kiambu county is characterized by both small scale and large scale agricultural activities. There are cash crops like coffee and tea which are grown in both large scale and small scale. There is also flower farming, aquaculture and major quarrying activities.

3.2. Target Population

To achieve objective three, a population of 108 farms/households was targeted along the six (6) kilometer stretch of the river under study and those adjacent to the reservoir. According to Bartlet and Higgins (2011), a sample size of 55 individuals was appropriate for this study as it can be seen in appendix A_1.

3.3. Water sampling

Triplicate samples were drawn from each of the sampling points using simple random sampling method. A total of 24 samples were collected in each phase of the study (wet and dry season).The samples were stored in plastic sampling bottles which were thoroughly cleaned by washing in non-ionized detergent rinsed with tap water, and soaked in 10% HNO_3 for 24hrs and finally rinsed with non-ionized water prior to use. The bottles were rinsed with the water from each of the designated sampling points and then in-filled with water.

3.4. Sampling Procedure

To be able to establish the causes of degradation of Kiamumbi catchment, Simple random sampling method was used to come up with 55 respondents from the catchment neighbourhood.

3.5. Analytical procedures

The water samples were analyzed for various bacteriological and physico-chemical parameters during the wet month of June and dry month of September to study the seasonal variations of different parameters as described in “Standard methods for the examination of water and waste water 17th edition prepared and published jointly by American Public Health Association (APHA), American Water Works Association (AWWA) and Water Pollution Control Federation (WPCF) 2005.

3.5.1. Physical Parameters

The analyzed parameters were pH, Total Dissolved Solids, Turbidity and Electrical Conductivity.

3.5.1.1. pH

pH was analyzed at the sampling points using Portable pH meter 3071 by Jenways ,

3.5.1.2. TDS

TDS was analyzed at the sampling points using Portable TDS meter 4076 by Jenways,

3.5.1.3. EC

EC was analyzed at the sampling points using Portable Ec meter 4076 by Jenways ,

3.5.1.4. Turbidity

Turbidity was analyzed in the Laboratory using SGZ – B Portable turbidity meter Calibrated to 0.00 NTU using distilled water.

3.5.2. Heavy metals analysis

The heavy metals that were analyzed included; Zinc, Chromium, Copper, Calcium, Magnesium, Manganese, Cadmium, Nickel, Lead and Iron,. Analysis followed methods and procedures described in “Standard methods for the examination of water and waste water 17th edition prepared and published jointly by American Public Health Association(APHA), American Water Works Association (AWWA) and Water Pollution Control Federation (WPCF) 2005. These included Flame Atomic absorption Spectrometry for main heavy metals. In this method, a sample is aspirated into a flame and atomized. A light beam is directed through the flame into a monochrometor and onto a detector that measures the amount of light absorbed by the atomized element in the flame.

Because each metal has its own characteristic absorption wavelength, a source Lamp composed of that element is used; this makes the method relatively free from spectral or radiation interferences. The amount of energy at the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample over a limited concentration range. The AAS analysis was carried out in GK Chemistry Laboratory of JKUAT.

3.5.3. Analysis of ions

3.5.3.1. Chloride

Chloride was analysed using spectrophotometry method. The reagents used and the procedure were as indicated in appendix $A_{18.}$

3.5.3.2. Sulphate

Sulphate was analysed using spectrophotometry method. The reagents used and the procedure were as indicated in appendix $A_{19.}$

3.5.3.3. Phosphate

Phosphate was analysed using spectrophotometry method. The reagents used and the procedure were as indicated in appendix $A_{20.}$

3.6. Microbial Analysis.

This was done according to the standard methods for the examination of Water and waste water (APHA, 2005). The presence of micro-organisms was determined in three stages which are presumptive test, confirmed test and completed test.

3.6.1. Presumptive Test

A series of three tubes of lactose broth in three groups were inoculated with 10mls, 1ml and 0.1mls of the water. After incubation for 24 hours under 37˚C, there was lactose fermentation hence production of gas and the medium changed colour from Purple to yellow. This was a presumptive evidence of presence of coliforms. The *Most Probable Number* (MPN) of coliforms present in the water was determined by the number of positive tubes in reference to the table of computation of MPN.

3.6.2. The Confirmed Test

This was done by sub-culturing of the bacteria from the positive test. The bacteria were tested for the ability to grow and form colonies and produce gas in the same way on Levine's eosin methylene blue agar at 44ºC for 24 hours. Production of gas indicated the positive confirmed test.

3.6.3. Completed Test

This was the final check for colonies which appeared on the confirmatory media. It was done by inoculating a nutrient agar slant and a tube of lactose broth. After inoculation for 24 hours at 35ºC, the lactose broth was examined for gas production. A gram stained slide was made from the slant and the slide was examined under oil.

The organisms proved to be gram positive and this helped confirm presence of coliforms.

3.7. Isolation of Micro-organisms

After determining that micro-organisms were present, bio-chemical tests were undertaken to identify the specific micro-organisms. The tests undertaken included gram staining, Nitrate reduction, indole test, Methyl Red and Voges – Proskauer test, Catalase test, Gelatin liquifaction, Starch hydrolysis, Hydrogen sulphide production, Lactose fermentation, Urease test and Citrate Utilization. These biochemical tests were carried out following the manufacturer's directions as shown in appendix A_{16}.

3.8. KWT Water treatment method

In the current study, it was established that KWT uses a method that is not very advanced for water treatment. Alum, Soda and chlorine are the chemicals that are used. Aeration of raw water is done before introduction of the chemicals. The water is dosed with the three chemicals and is then introduced in the flocculation chamber tank where formation of flocks is enhanced. Clean water is allowed to flow into the final chamber which directs the water into the sand filtration system. The filtered water through the media is later allowed into the main reservoir of treated water. From this reservoir the water is pumped into the main distribution – 225m^3 then supplied to the consumers. The quantity of water supplied to the consumers per day is 983m^3 per day. This is a simple method of treating water from sources prone to pollution and thus the need to establish the quality of the same.

3.9. Data Analysis

The collected data was subjected to statistical analysis using Microsoft excel package and SPSS. Microsoft excel package was used to determine the mean and standard deviation. The *t-test* was used to establish whether there existed any significance difference between concentration levels of pollutants in the wet and dry season and also on the feeder river and the reservoir. *T-test* is based on *t-* distribution and is considered an appropriate test for judging the significance of a sample mean or for judging the significance of difference between the means of two samples in case of small sample(s) when population variance is not known. In case two samples are related, *paired t-test* is appropriate for judging the significance of the mean of difference between the two related samples as it was the case in this study.

CHAPTER FOUR

RESEARCH RESULTS AND DISCUSSION

4.0. General Overview

This chapter contains detailed analysis of collected data from the water points and selected households. The results are presented in form of tables and graphs where applicable. Critical inferential data analysis and discussions are offered where applicable.

4.1. Physico – Chemical Parameters.

The results obtained from all the sampling points are presented in Tables and graphs

4.1.1. Turbidity (NTU)

The mean levels of turbidity on the feeder river, reservoir and the storage facility during the wet and dry seasons were as presented in Figure 4.1 below.

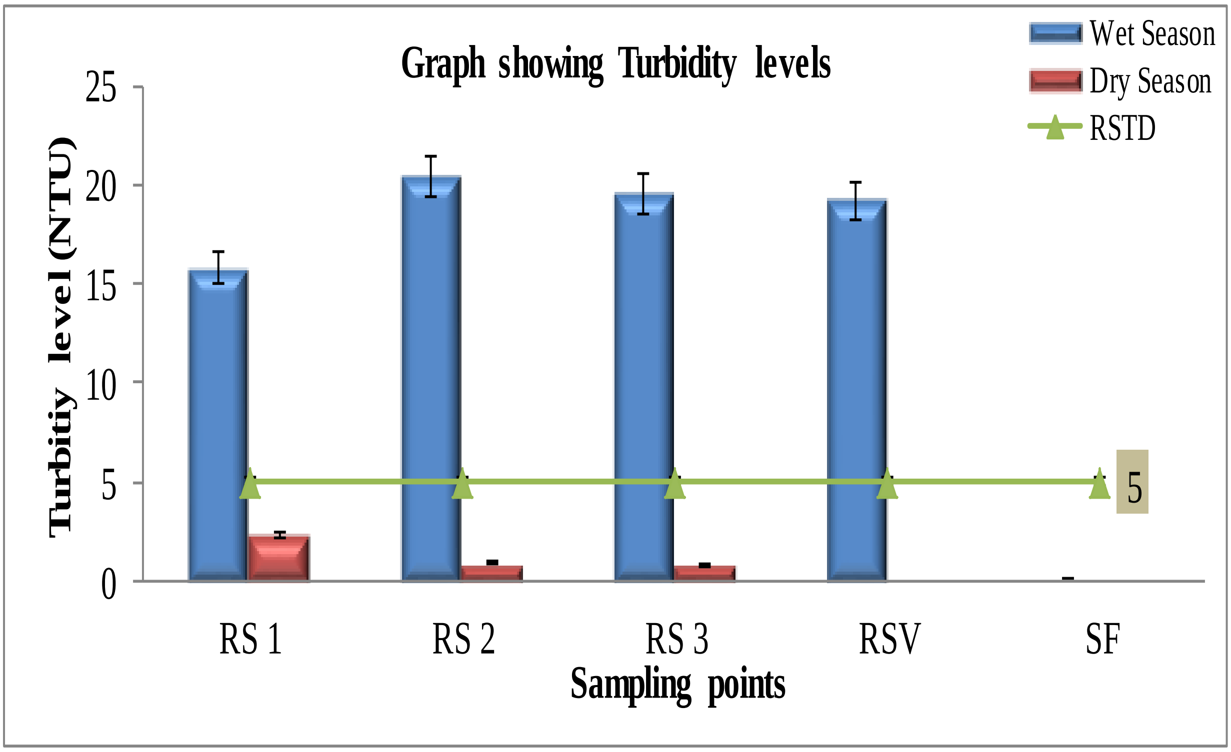


Figure 4.1: Turbidity levels during the wet and dry seasons

In this study, turbidity levels were as presented in Appendices A_2 and Figure 4.1. The results showed that the turbidity levels were above the recommended levels in the river and the reservoir only during the wet season. The highest mean concentration was 20.5 ± 0.85 NTU recorded at the second sampling point of the feeder river. The levels were high during the wet season because there is a lot of run – off that carries eroded soils resulting from poor farming methods, and non- rehabilitated quarries. Also, run-off deposits plant remains, oils and grease, sewage, animal waste, fertilizers among other organic and inorganic pollutants into the feeder river and the reservoir. The turbidity levels at the storage facility in both wet and dry season were far below allowable levels with the highest level recorded being 0.17 ± 0.64NTU.

The levels in the river ranged from 13.6 NTU– 27.2 NTU during the wet season and 4.80 NTU to 20.27 NTU during the dry season. The high levels of turbidity during the wet season are attributed to high run-off with increased soil erosion.

The *t-test* results indicated that there was a significance difference in levels of turbidity during the wet and dry season where t_{cal} $(8)=3.720>t_{tab}=2.306$, $P_{cal}0.006 <P_{tab}=0.05$. This difference can be attributed to run-off and related soil erosion and other dissolved substances during the wet season because of heavy rains. While comparing the levels of turbidity between the feeder river and the reservoir, the *t-test* results indicated a significance difference during the dry season where $t_{cal}(19)=3.88>t_{tab}=2.093$, $P_{cal}0.001 <P_{tab}=0.05$ but there was no significance difference during the wet season where $t_{cal}(19)=0.4<t_{tab}=2.306$, $P_{cal} =0.696>P_{tab}=0.05$. The significance difference during the dry season between the levels of turbidity between the river and the reservoir can be attributed to the ability of the river to erode its banks, but this natural event reduces as one approach the reservoir noting that in the reservoir there is not erosion.

The mean turbidity level in Kiamumbi catchment for the two seasons was found to be 7.96 implying that the levels are above the acceptable limits for water for domestic use. These high levels imply that there is high soil erosion resulting to suspended particles in the water. Also, turbidity favours survival of micro-organisms and this explains their established presence in the catchment.

4.1.2. pH

The pH value was as presented in Figure 4.2 below.

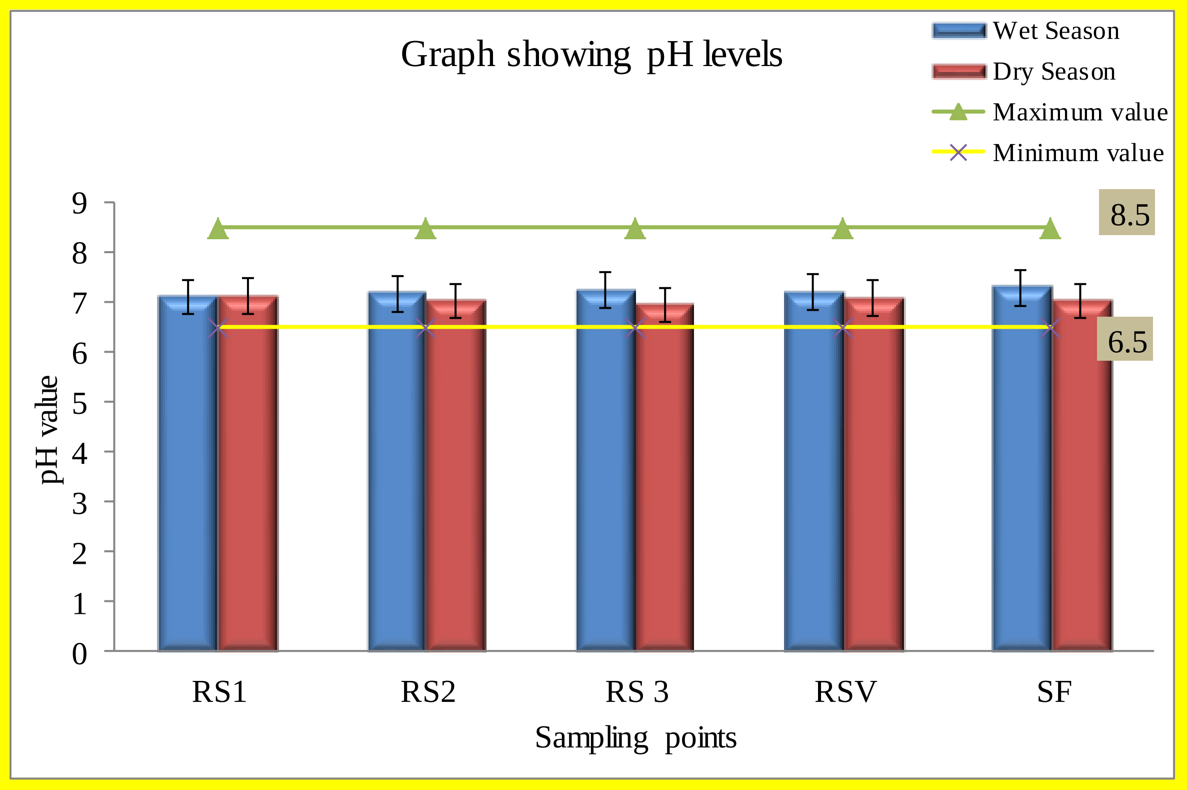


Figure 4.2: pH level during wet and dry seasons

In this study, the mean pH at the different sampling points was as presented in appendix A_3 and figure 4.2. The pH was found to fall within the recommended levels during the wet and dry season. However, due to increased pollution during the wet season, pH levels were higher than in the dry season. The highest mean pH value was 7.24 ± 0.06 recorded at the third sampling point at the feeder river during the wet season while the lowest level was 6.96 ± 0.09 recorded at the third sampling point of the feeder river (6km upstream) from the reservoir during the dry season. The mean pH level in the reservoir was 7.2 ±0.01 during the wet season and 7.09 ± 0.14 during the dry season. The mean pH level in the storage facility during the wet season was 7.3 ± 0.07 while during the dry season it was 7.03 ± 0.04. In the river, pH value ranged from 7.05 - 7.27 during the wet season and 6.88- 7.37 during the dry season. In the reservoir, pH value ranged from 7.01 – 7.32 during the wet season and 6.90 – 7.37 during the dry season.

The *t-test* results indicated that there was a significance difference between pH level during the wet season and the dry season where $t_{cal}(8)=3.884>t_{tab}=2.306$, $P_{cal}0.05 =P_{tab}=0.05$. The significance difference can be attributed to dissolved substances during the wet season which has the ability to increase the pH which are related to high levels of turbidity. However, there was no significance difference in pH levels between the feeder river and the reservoir where during the wet season $t_{cal}(19)=0.47>t_{tab}=2.093$, $P_{cal}0.641>=P_{tab}=0.05$ while during the dry season $t_{cal}=1.05>t_{tab}=2.093$, $P_{cal}\,0.309>=P_{tab}=0.0.5$

pH is one of the most important operational water quality parameters. The mean pH level in the catchment was found to be 7.13 implying the water is consumable. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. For effective disinfection with chlorine, the pH should be less than 8, however, pH less than 7 acidic and corrosive. pH of water determines the solubility and biological availability of chemical constituents such as nutrients like phosphorous and heavy metals like Lead, cadmium and chromium. The degree to which heavy metals are soluble determine their toxicity. Metals tend to be more toxic at lower pH because they are more soluble.

This implies that the level of pollution of the catchment by heavy metals is very high because even at neutral pH, metals like cadmium, Lead and Chromium were found to be above acceptable levels. The pH value in this study was found to be at a level that supports optimal survival of micro-organisms and this explains the high coliforms present.

4.1.3. Total Dissolved Solids (TDS)

The TDS levels were as presented in the Figure 4.3 below

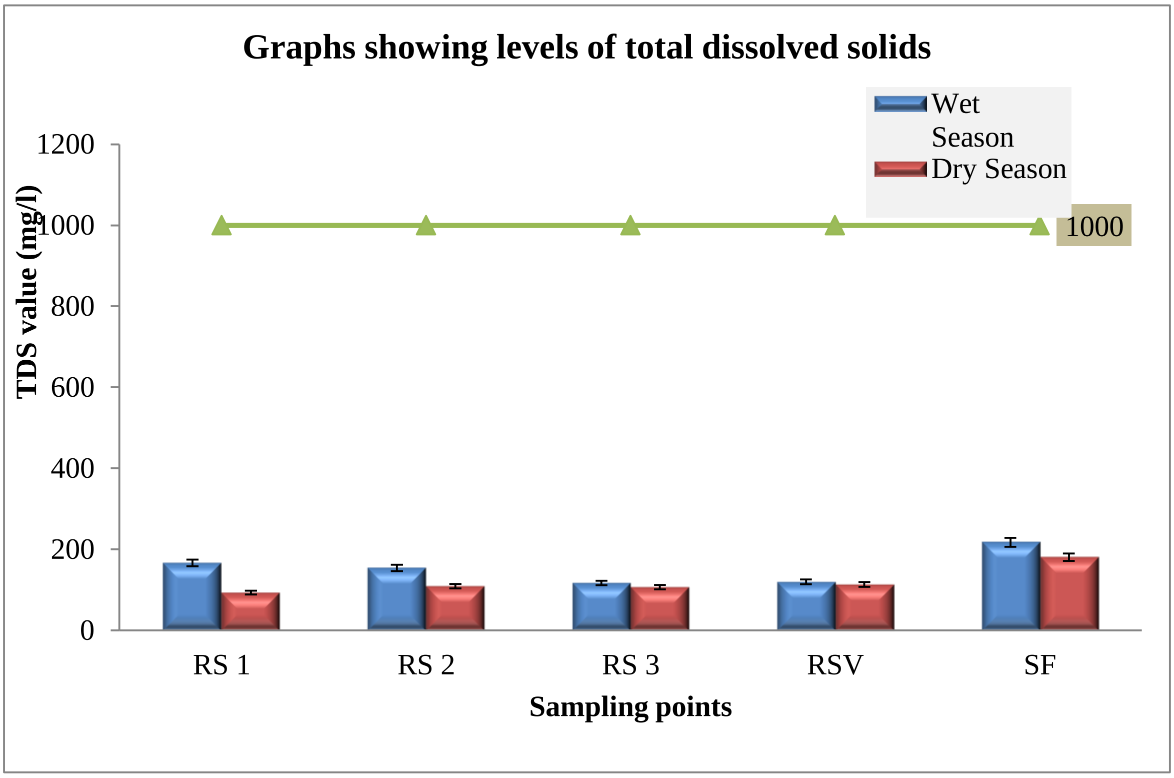


Figure 4.3: Total Dissolved solids during wet and dry seasons

The results of this study as presented in appendices A_4 and figure 4.3 indicates that the TDS levels were found to be below the recommended standards for drinking water in all sampling points in both dry and wet season. That notwithstanding, the highest mean level was recorded at the storage facility which was 217.3 ± 21.5 mg/l during the wet season. The lowest mean level was 93.2 ± 2.14 mg/l recorded at the first sampling point of the river during the dry season. The levels of TDS were high during the wet season in the storage facility because the management increases the amount of chemicals used for water treatment like chlorine, soda and alum and they are transferred to the storage facility in residual form. The lowest mean TDS level during the wet season was 116.9 ± 2.06mg/l at the third sampling point at the feeder-river. The TDS levels ranged from 112.5 mg/L – 137.3 mg/L in the in the reservoir during the wet season and 110.8 mg/L to 117.8 mg/L during the dry season. In the storage facility, the levels ranged from 187mg/L – 233 mg/L during the dry season. In the feeder river the levels ranged from 107.3 mg/L – 182.2 mg/L during the wet season and 91.6 mg/L – 111.2 mg/L during the dry season.

The *t-test* established that there was no significance difference between the levels of TDS during the wet and dry season where $t_{cal}(8)=1.433<t_{tab}=2.306$, P_{cal} $0.19 >P_{tab}=0.05$. However, there was a significance difference between the levels of TDS between the feeder river and the reservoir in both seasons where during the wet season where $t_{cal}(19)=3.63>t_{tab}=2.093$, P_{cal} $0.021 <P_{tab}=0.05$ and during the dry season $t_{cal}(19)=3.63>t_{tab}=2.093$, P_{cal} $0.021 <P_{tab}=0.05$.The significance difference between levels of TDS between the feeder river and the reservoir can be attributed to the fact that the river carries along with it a lot of substances as it also receives a lot of the substances from run-off and erosion as it flows through its course and at the same time the river undergoes natural cleansing before draining into the reservoir.

The mean TDS level in the catchment was found to be 137.7 mg/L. Water with TDS levels of less than 600mg/L is generally considered to be good drinking water but it becomes significantly and increasingly unpalatable at TDS levels greater than 100mg/L (WHO, 2011).

4.1.4. Electrical Conductivity (µS)

The EC levels were as presented in Figure 4.4 below.

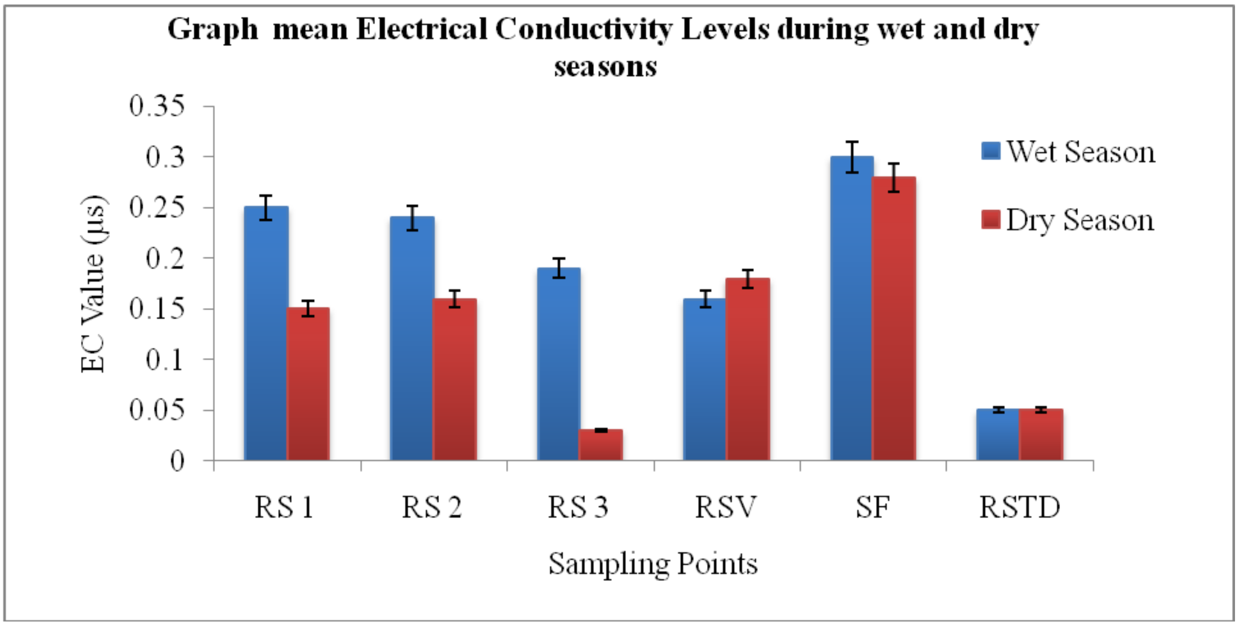


Figure 4.4: Electrical conductivity during wet and dry seasons

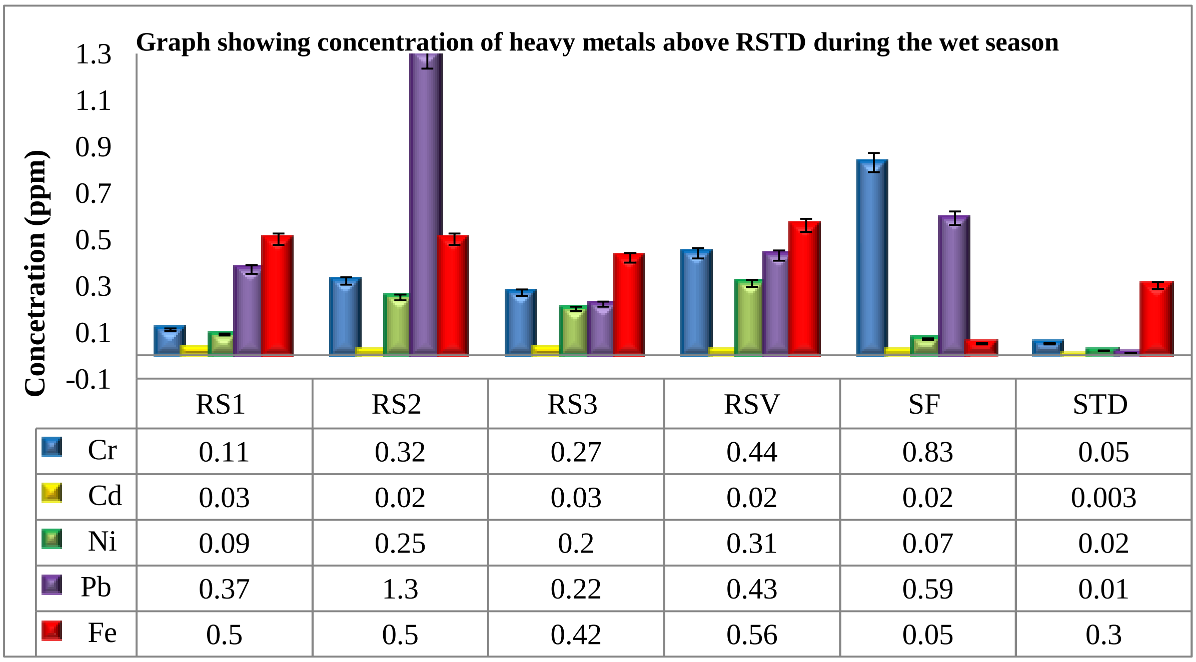
The recommended level for electrical conductivity in drinking water is 0.05 µS. The levels of electrical conductivity recorded in this study in all sampling points were as presented in appendices A_5 and Figure 4.4. The mean EC levels during the wet season were higher than during the dry season. The highest EC level was 0.3 ± 0.02 µS measured at the storage facility during the wet season, while the lowest was 0.03 ± 0 µS recorded at the third sampling point in the river during the dry season. EC level ranged from 0.18 µS – 0.27 µS in the feeder river during the wet season and 0.03 µS – 0.17 µS during the dry season. In the reservoir, the levels ranged from 0.13 µS – 0.21 µS during the wet season and 0.2 µS – 0.16 µS during the dry season. The EC Levels in the storage facility during the wet season ranged from 0.28 µS – 0.32 µS while during the dry season they were constantly at 0.28 µS.

The *t-test* indicated that there was no significance difference between the levels of EC between the wet and dry seasons where $t_{cal}=1.455<t_{tab}=2.306$, P_{cal} $0.184 >P_{tab}=0.05$.However there was a significance difference in EC levels between the feeder river and the reservoir in both seasons. During wet season, $t_{cal}=2.53>t_{tab}=2.093$, P_{cal} $0.021 <P_{tab}=0.05$ *and during the dry season,* $t_{cal}=3.51>t_{tab}=2.093$, P_{cal} $0.002 <P_{tab}=0.05$.

The levels were higher in the storage facility than in the river and the reservoir and this can be attributed to residual chemicals like chlorine and aluminium sulphate used to treat the water. The mean Electrical conductivity level in the catchment was found to be 0.2 µS. Although there is little direct health risk associated with high conductivity values, such values are associated with poor-tasting water and customer dissatisfaction and complaints. Changes in conductivity with time, or high conductivity values, can both indicate that the water has become contaminated for example from saline intrusion, faecal pollution, or nitrate pollution). Over time, the contamination can cause corrosion in rising mains and pipes.

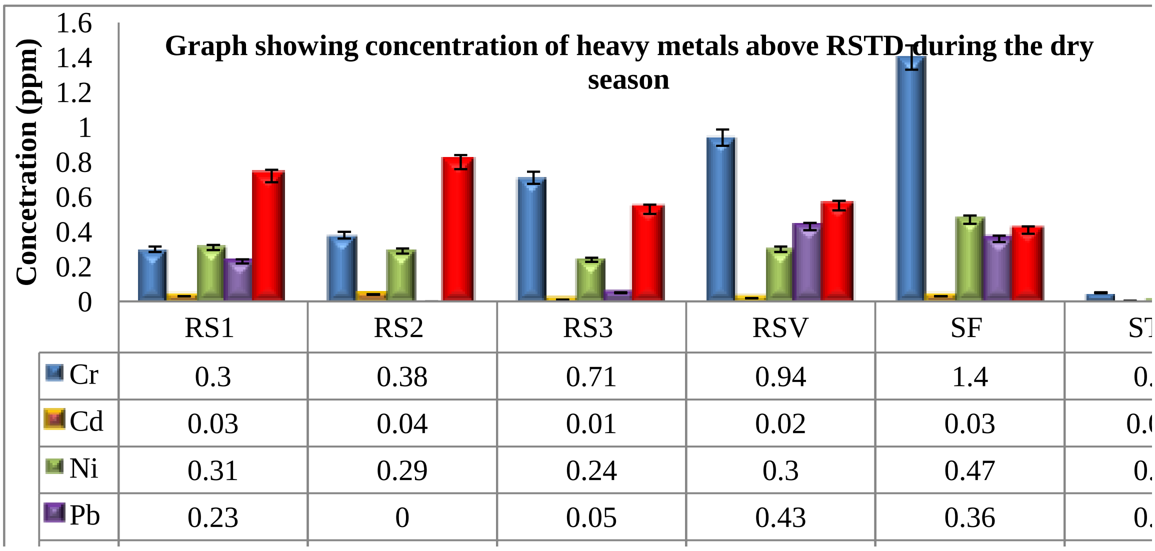
4.1.5. Heavy metals

A total of ten (10) heavy metals were analyzed. These included Zinc, Chromium, Copper, Calcium, Magnesium, Manganese, Cadmium, Nickel, Lead and Iron. The mean concentration of the heavy metals that were found to be above recommended levels in different sampling points were as presented in Appendix A_6 and Appendix A_7 and figures 4.5.and 4.6 below. The range and the standard deviations are presented in the respective appendices.



	RS1	RS2	RS3	RSV	SF	STD
🟦 Cr	0.11	0.32	0.27	0.44	0.83	0.05
🟨 Cd	0.03	0.02	0.03	0.02	0.02	0.003
🟩 Ni	0.09	0.25	0.2	0.31	0.07	0.02
🟪 Pb	0.37	1.3	0.22	0.43	0.59	0.01
🟥 Fe	0.5	0.5	0.42	0.56	0.05	0.3

Figure 4.5: Concentration of heavy metals above RSTD during wet season



	RS1	RS2	RS3	RSV	SF	S
Cr	0.3	0.38	0.71	0.94	1.4	0.
Cd	0.03	0.04	0.01	0.02	0.03	0.
Ni	0.31	0.29	0.24	0.3	0.47	0.
Pb	0.23	0	0.05	0.43	0.36	0.

Figure 4.6: Concentration of heavy metals above RSTD during the dry season

In accordance to the findings of this study, concentration of Chromium, Cadmium, Lead, Nickel and Iron was found to be above the recommended levels for drinking water in both the wet and the dry season even after treatment.

Consumption of water contaminated with heavy metals may result to serious human health impacts. For example Cadmium accumulates primarily in the kidneys and has a long biological half-life in humans of 10-35 years. According to WHO, Cadmium is classified as probably carcinogenic to humans. Exposure to Lead is associated with a wide range of effects, including various neurodevelopment effects, mortality, impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes. Nickel and Chromium are also suspected to be carcinogenic (WHO, 2011).

Figure 4.5 shows that Chromium, Cadmium, Nickel and Iron were highly concentrated in the storage facility during the dry season than in the wet season.

These heavy metals were found to be present in the storage facility meaning that the treatment method is ineffective in reduction of heavy metals in water.

4.1.5.1. Chromium

In this study the mean concentration of Chromium was found to be above the recommended level of 0.05 mg/L. The highest concentration level was 1.4 ± 0.17 mg/L recorded at the storage facility during the dry season and lowest level was 0.11 ± 0.07 mg/L recorded at the first sampling point of the river during the wet season.

The *t-test* indicated that there was not significance difference in the concentration of chromium between the wet season and dry season where $t_{cal}(8)=1.506<t_{tab}=2.306$, $P_{cal}\ 0.171>P_{tab}=0.05$.There was also no significance difference in concentration of chromium between the feeder river and the reservoir where during the wet season $t_{cal}(19)=2.006<t_{tab}=2.093$, $P_{cal}\ 0.06>P_{tab}=0.05$ and during the dry season season $t_{cal}(19)=1.558<t_{tab}=2.093$, $P_{cal}\ 0.136>P_{tab}=0.05$.

The concentration of chromium increased exponentially from the first sampling point in the feeder river downstream to the reservoir and the highest concentration was recorded at the storage facility. This can be attributed to accumulated quantities as a result of on-route collection of chromium by the feeder-river and also different sources from areas near each sampling point. Chromium present within the catchment may result from paints washed away by surface run-off. Presence of chromium can also be attributed to leaching from top soil and rocks.

4.1.5.2. Cadmium

The concentration of Cadmium was found to be above the recommended level of water for domestic use. The highest mean concentration of cadmium was 0.04 ± 0.007 mg/l recorded at the second sampling point of the feeder river during the wet season and the lowest was 0.01 ± 0.013 mg/l recorded at the third sampling point in the river during the dry season. The *t-test* indicated that there was significance difference in concentration of cadmium between the wet season and dry season where $t_{cal}(8)=0.354<t_{tab}=2.306$, P_{cal} $0.733 >P_{tab}=0.05$. There was also no significance difference in concentration of cadmium between the feeder river and the reservoir where during the wet season $t_{cal}(19)=0.368<t_{tab}=2.093$, P_{cal} $0.717 >P_{tab}=0.05$ and during the dry season $t_{cal}(19)=0.971<t_{tab}=2.093$, P_{cal} $0.344 >P_{tab}=0.05$.

Cadmium is released to the environment in waste water and diffuse pollution is caused by contamination from fertilizers and local air pollution. In this study, it was established that use of fertilizers in farms was a major source of pollutants and this explains the high levels of Cadmium present in the catchment. Cadmium may also enter water bodies through weathering and erosion of soils and bedrocks, atmospheric deposition, direct discharge from industrial operations and leakage from Landfalls.

4.1.5.3. Nickel

The concentration levels were found to be above 0.02 mg/L which is the WHO recommended level. During the wet season, the highest mean concentration of Nickel was 0.47 ±0.18 mg/L at the storage facility and the lowest mean concentration was 0.07 ± 0.07 mg/L at the storage facility during the wet season. There was no significance difference in the concentration of Nickel between the wet season and dry season where $t_{cal}(8)=2.29<t_{tab}=2.306, P_{cal}\ 0.051 > P_{tab}=0.05$. There was also no significance difference in concentration of Nickel at nineteen (19) degrees of freedom between the feeder river and the reservoir in both seasons where during the wet season $t_{cal}(19)=1.632<t_{tab}=2.093, P_{cal}\ 0.119 > P_{tab}=0.05$ and during the dry season $t_{cal}(19)=1.194<t_{tab}=2.093, P_{cal}\ 0.247 > P_{tab}=0.05$.

The mean concentration of Nickel in the catchment was found to be 0.23 mg/L. The concentration in the storage facility was the highest indicating the ineffectiveness of the water treatment method in reduction of Nickel. The main source of Nickel in the catchment would be mainly run-off from garages, leaching from metal pipes used to pump water from the treatment facility to the storage facility. Studies have shown that Nickel can be excreted in human faeces and urine and this may be a possible source of Nickel within the catchment from sewage.

4.1.5.4. Lead

The mean concentration levels were found to be above 0.01 mg/L which is the WHO recommended level. During the wet season the highest mean concentration level was 1.3 ± 0.83 mg/l at the second sampling point in the feeder river and the lowest mean concentration was 0.0 ± 0.04 mg/L at the second sampling point in the feeder river during the dry season. The highest mean concentration during the dry season was 0.43 ± 0.21 mg/L at the reservoir.

The *t-test* results indicated that there was no significance difference in concentration of Lead between the wet and dry seasons where $t_{cal}(8)=1.779<t_{tab}=2.306$, P_{cal} $0.113 > P_{tab}=0.05$. Also, there was no significance difference in concentration of Lead between the feeder river and the reservoir during both seasons. During the wet season $t_{cal}(19)=1.373<t_{tab}=2.093, P_{cal}=0.186>P_{tab}=0.05$ and during the dry season $t_{cal}(19)=1.780<t_{tab}=2.093$, P_{cal} $0.091 > P_{tab}=0.05$.

The mean concentration of Lead in the catchment was found to be 0.33 mg/L. Lead is rarely present in tap water as a result of its dissolution from natural sources, rather its presence is primarily from corrosive water effects on household plumbing systems containing lead in pipes, solder, fittings or the service connections in the homes. The amount of Lead dissolved from plumbing systems depends on several factors including pH. This explains the high levels of Lead concentration in the storage facility and it is also an indication of the ineffectiveness of the water treatment method in lead reduction. There was also high concentration of Lead in the reservoir which can be attributed to run-off from garages, workshops in the shopping centres and market places within the catchment and sewage effluents washed away by run-off. After domestic use of lead contaminated water and subsequent disposal, Lead finds its way into water bodies through run-off and leaching. Run – off from and through small businesses like garages and work-shops all over the catchment can be a good source of Lead into the surface water in Kiamumbi catchment

4.1.5.5. Iron

The mean concentration of Iron in the catchment was found to be 0.46 mg/L. This was above the recommended levels of 0.3 mg/L except at the storage facility during wet season which was recorded at 0.05 ± 0.03 mg/L. The highest mean concentration was 0.56 ± 0.29 mg/L at the reservoir during the wet season. During the dry season, the highest concentration was 0.8 ± 0.26 mg/L at the second sampling point in the river while the lowest was 0.41 ± 0.07 mg/L at the storage facility.

The *t-test results* indicated that there was no significance difference in concentration of Iron between the wet and dry season where $t_{cal}(8)=1.699<t_{tab}=2.306$, P_{cal} $0.128 >P_{tab}=0.05$.There was also no significance difference in concentration of iron between the feeder river and reservoir in during the wet season where $t_{cal}(19)=1.887<t_{tab}=2.093, P_{cal}=0.074>P_{tab}=0.05$ but there was a significance difference during the dry season $t_{cal}(19)=2.19>t_{tab}=2.093$, P_{cal} $0.041 <P_{tab}=0.05$.

The iron concentration can be attributed to paints washed away by run-off from ongoing construction works, while in the storage facility iron may be resulting from chemicals used for water treatment. It can also be attributed to weathering of rocks and run-off through quarry sites. Iron promotes the growth of ‘iron Bacteria’. At levels above 0.3mg/L, iron stains laundry and plumbing fixtures. There is usually no noticeable taste at iron concentrations below 0.3 mg/L, although turbidity may occur (WHO, 2011).

4.2. Nutrients

Analysis was done for Phosphate and Sulphate.

4.2.1. Phosphates

The figure 4.7 below illustrates mean concentration of phosphate in different sampling points during wet and dry season.

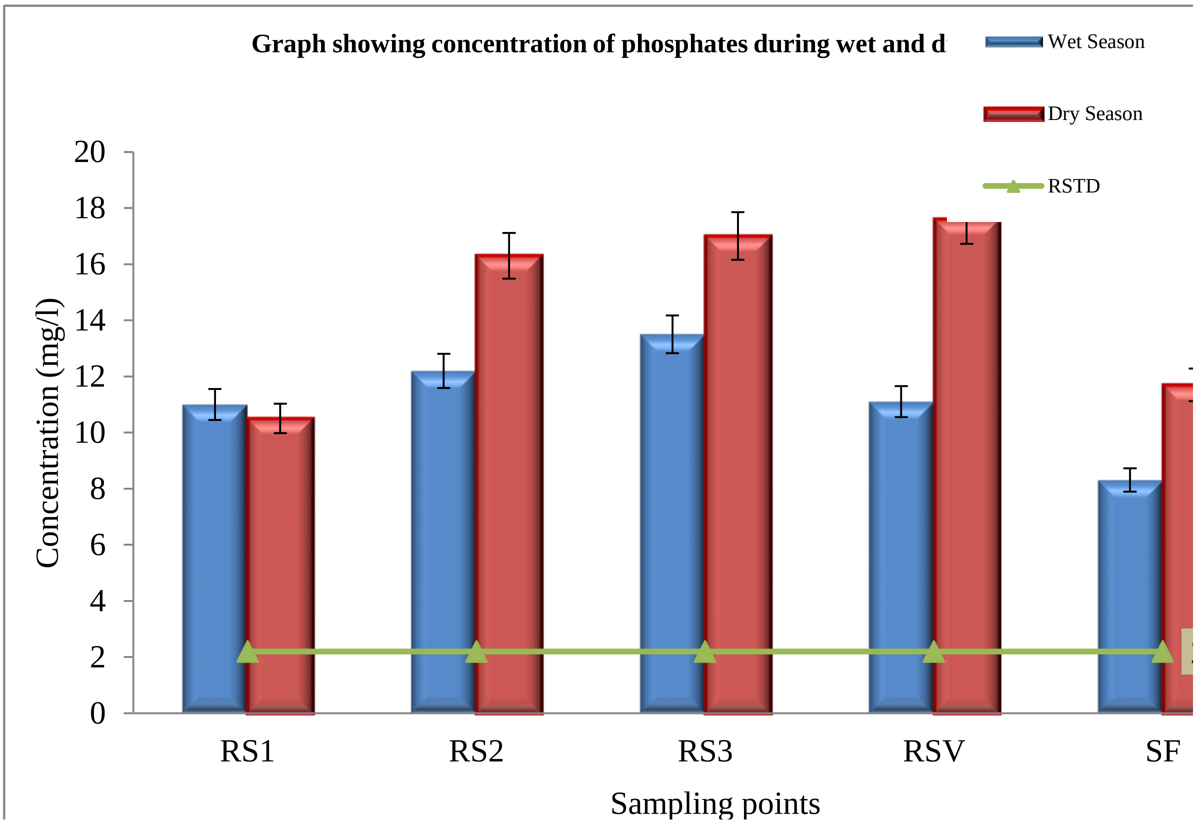


Figure 4.7: Concentration of Phosphates during wet and dry seasons

The mean concentration of Phosphates was found to be as presented in appendix A_8 and Figure 4.7.below. The mean concentration was found to be above the recommended standard of 2.2 mg/L in all sampling points during both wet and dry season. During the wet season, the highest mean concentration was 13.5 ± 1.97 mg/L at the third sampling point of the feeder river and the lowest was 8.31 ± 2.62 mg/l at the storage facility. During the dry season, the highest concentration level was found to be 17.6 ± 4.27 mg/L in the reservoir while the lowest was 10.5 ± 0.34 mg/l at the first sampling point at the feeder river. The mean concentration of phosphate ranged from 7.33 mg/L – 15.35 mg/L during the wet season in the feeder river while during the dry season it ranged from 14.05 mg/L -19.64 mg/L. In the reservoir, the mean concentration ranged from 6.96 mg/L - 9.94 mg/L during the wet season and 8.76 mg/L – 12.46 mg/L during the dry season. The mean concentration in the storage facility during the wet season ranged from 5.28 mg/L – 9.94 mg/L during the wet season and 8.76 mg/L – 12.46 mg/L during the dry season.

The *t-test* results at 95% confidence level, indicated that there was no significance difference in concentration of phosphates between the wet and dry season where $t_{cal}(8)=2.003<t_{tab}=2.306$, P_{cal} $0.08 > P_{tab}=0.05$.There was also no significance difference in the concentration of phosphate between the feeder river and the reservoir during the wet season where $t_{cal}(19)=0.830<t_{tab}=2.093, P_{cal}=0.417>P_{tab}=0.05$. However during the dry season the was a significance difference where $t_{cal}(19)=3.448<t_{tab}=2.093, P_{cal}=0.003>P_{tab}=0.05$.

From Figure 4.7, it can be observed that the concentration of phosphates was higher during the dry season than in the wet season. The mean concentration of Phosphate was found to be 12.36 mg/L. In this study, there was a sharp increase in phosphates concentration between the first and the second sampling point along the river. This is the point where there are huge coffee plantations and extensive farming activities along the catchment. These activities reduces as one moves downstream but due to accumulated collection of phosphates by the river and deposition through run-off direct into the reservoir, the level of phosphates was high at the reservoir than along the river in both seasons. The level gradually reduces in the storage facility but it should be noted that even after treatment of the water, the concentration levels were beyond the recommended standard. This was attributed to the ineffectiveness of the treatment method. The high levels of phosphorous can be attributed to phosphate fertilizers used in farms washed away by run off and this explains the high levels during the wet season. It can also be attributed to decal of some plants and weathering of rocks.

Phosphorus does not pose a direct threat to human health; it is an essential component of all cells and is present in bones and teeth. It does, however, pose an indirect threat to both aesthetics and to human health by affecting source waters used for drinking and recreation. For example, excessive nutrients can promote the growth of algal blooms, which can contribute to a wide range of water quality problems by affecting the portability, taste, odour, and colour of the water.

4.2.2. Sulphates

The mean concentration of sulphate in the different sampling points was as presented in figure 4.8 below during wet and dry season.

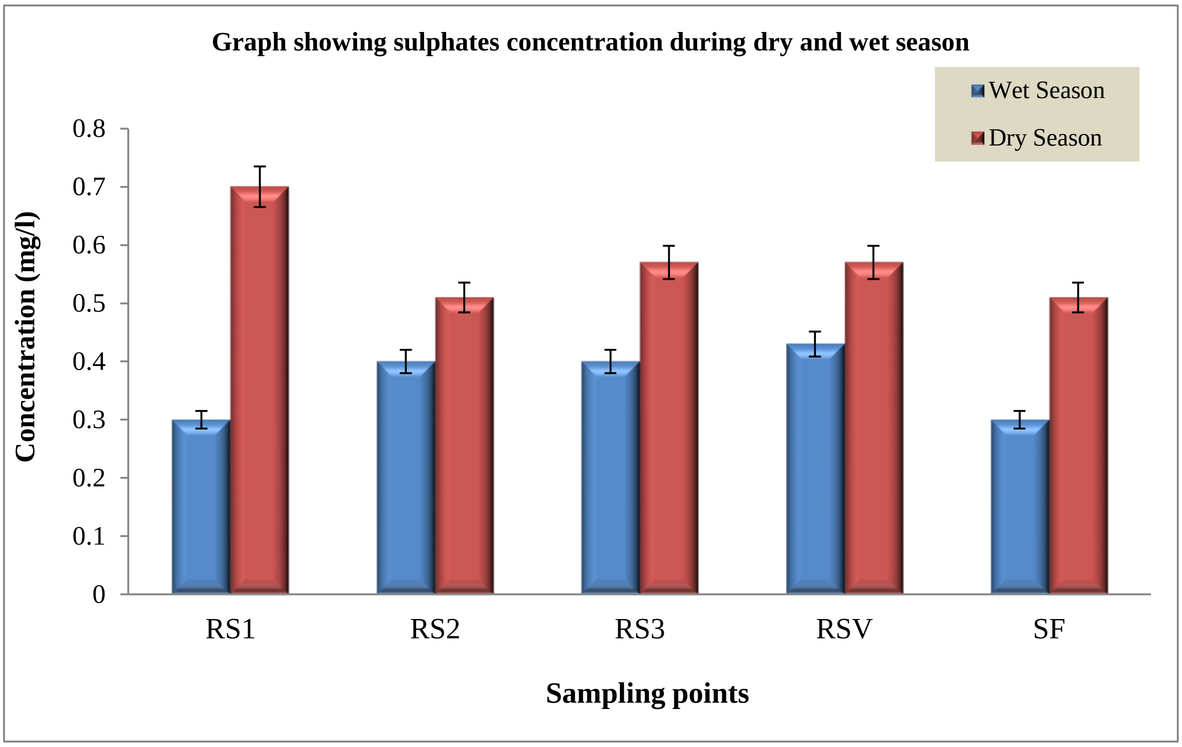


Figure 4.8: Sulphates concentration during wet and dry seasons

The concentration of sulphate at the different sampling points was as presented in appendix A_9 and Figure 4.8 below. The findings of this study showed that the concentration levels of sulphates were below the recommended levels of 400 mg/L. The highest mean concentration recorded was during the dry season at 0.7 ± 0.01 mg/L at the first sampling point of the feeder river while the lowest was 0.51 ± 0.06 mg/L at both the second sampling point of the feeder river and the storage facility. During the wet season the highest mean concentration was 0.43 ± 0.11 mg/L recorded at the reservoir and the lowest mean concentration was 0.3 ± 0.23 mg/L and 0.3 ± 0.27 mg/L in both the first sampling point of the feeder river and the storage facility respectively.

The mean concentration of sulphate in the catchment was found to be 0.5 mg/L and it ranged from 0 mg/L – 0.5 mg/L during the wet season and 0.5 mg/L – 0.62 mg/L during the dry season in the feeder river. In the reservoir, the concentration ranged from 0.1 mg/L to 0.5 mg/L during the wet season and 0.3 mg/L to 1.3 mg/L during the dry season. The mean concentration in the storage facility ranged from 0.1 mg/L to 0.6 mg/L during the wet season and 0.66 mg/L to 0.77 mg/L during the dry season.

The *t-test* result indicated that there was a significance difference in the concentration of suphate between the wet season and dry season where $t_{cal}(8)=4.653>t_{tab}=2.306, P_{cal}=0.08 >P_{tab}=0.05$. However, there was no significance difference in concentration of sulphate between the feeder river and the reservoir during both seasons. During the wet season $t_{cal}(19)=1.548<t_{tab}=2.093, P_{cal}=0.138>P_{tab}=0.05$ and during the dry season $t_{cal}(19)=0.500<t_{tab}=2.093, P_{cal}\, 0.623 >P_{tab}=0.05$.

The concentration of sulphate in the storage facility may be attributed to residual from use of alum in excess during the wet season for water treatment. It can also be attributed to fertilizers, chemicals, dyes, glass, paper, soaps, textiles, fungicides, insecticides, astringents and cosmetics processing washed into the catchment by run-off. High concentration of sulphate in drinking water can cause transitory diarrhea.

4.2.3. Chloride

Table 4.1. below shows the concentration of chloride ions in the catchment as established during this study.

Sampling points	**Wet season**		**Dry Season**	
	Range	**$\bar{x}$ ±Stdev**	**Range**	**$\bar{x}$ ±Stdev**
RS1	713.38 – 934.08	794 ± 121.55	7.89 – 8.20	11 ± 0.15
RS2	669.24 – 889.94	809 ± 121.55	8.04 – 9.75	8.04 ± 0.86
RS3	382.33 – 603.03	504 ± 113.25	7.58 – 9.75	8.97 ± 1.21
RSV	603.03 – 867.87	741 ± 116.8	4.80 – 20.27	8.97 ± 4.17
SF	492.7 - 580	544 ± 46	10.36 – 12.07	7.9 ± 0.94
RSTD		**250**		**250**

Table 4. 1: Concentration of Chloride during wet and dry seasons

The highest recorded mean concentration of chloride was 809 ± 121.55 mg/L in the wet season and the lowest recorded mean concentration was 7.9 ± 0.94 mg/L during the dry season. At 95% confidence level, the *t-test* results indicated that there was a significance difference between the wet and the dry season where $t_{cal}(8)=10.403>t_{tab}=2.306, P_{cal}=0.0 <P_{tab}=0.05$. However, there was no significance difference in concentration of chloride between the feeder river and the reservoir during both seasons where during the wet season $t_{cal}(19)=1.548<t_{tab}=2.093, P_{cal}=0.138>P_{tab}=0.05$ and during the dry season $t_{cal}(19)=0.500<t_{tab}=2.093,\ P_{cal}\ 0.623 >P_{tab}=0.05$.

The mean chloride concentration in the catchment was found to be 355.5 mg/L. Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban run-off containing salts and saline intrusion. Excessive chloride concentration is known to increase rates of corrosion of metals in the distribution system (WHO, 2011) depending on the alkalinity of the water. High concentrations of Chloride give a salty taste to water. Concentrations in excess of 250 mg/L are increasingly likely to be detected by taste (WHO, 2011).

4.3. Bacteriological Quality

There were different micro-organisms identified in the water in the feeder river and the reservoir. There were no micro-organisms found in the storage facility in both dry and wet season a clear indication of the effectiveness of the water treatment method in place in removal of micro-organisms.

4.3.1. Identified Micro-organisms

The micro-organisms that were found in the river and the reservoir in both dry and the wet season were as presented in Table 4.2.

	Wet Season		**Dry Season**	
Micro-Organisms	**Feeder River**	**Reservoir**	**Feeder River**	**Reservoir**
Salmonella	+	_	_	+
Pseudomonus Aeruginosa	+	+	_	_
Shigella Dysentriae	+	+	+	+
Streptococcus	+	+	_	_
Escherichia Coli	_	+	_	+
Enterobacter Aerogenes	_	+	+	+
Citrobacter Freundii	_	_	+	+
Klebsiella Oxycota	_	_	+	+
Proteus Vulgaris	_	_	+	+

Table 4. 2: Micro-organisms identified in the river and reservoir during wet and dry season

The results of this study indicated that the water in the feeder river and the reservoir was contaminated with nine different micro-organisms. *Shigella dysentriae* was the most dominant microorganism. *Streptococcus* and *Pseudomonus aeruginosa* were only present in the river.

It was also discovered that the water treatment method in place was very effective in disinfecting the water from microbial pollutants because samples from the storage facility did not show presence of any micro-organisms. The presence of *Escherichia coli*, *Shigella* and *Klebsiella* was an indication of faecal contamination of water in the catchment. The most dominant micro-organism was *Shigella dysentriae* which was present in the feeder river and the reservoir in both seasons.

Micro-Organisms	**Wet Season**	**Dry Season**
Salmonella	+	+
Pseudomonus Aeruginosa	_	+
Shigella Dysentriae	+	+
Streptococcus	_	+
Escherichia Coli	+	+
Enterobacter Aerogenes	+	+
Citrobacter Freundii	+	_
Klebsiella Oxycota	+	_
Proteus Vulgaris	+	_

Table 4. 3: Comparison of Micro-organisms identified during wet and dry season

The results of this study showed that there was a common source of some micro-organisms in both wet and dry season. This is based on the fact that out of the nine micro-organisms identified in this study, four of them were present in both seasons as shown in table 4.3 above. These were *Salmonella, Shigella Dysentriae, Escherichia coli* and *Enterobacter aerogenes.* This may be as a result of contamination of surface run-off with sewage and wild animal excreta.

The findings of this study indicated that there was a difference in micro-organisms present in both seasons. This was because out of the nine micro-organisms identified, two of them namely *Pseudomonous aeruginosa* and *Streptococcus* were present only during the dry season while *Klebsiella oxycota*, *Proteus vulgaris* and *Citrobacter freundii* were present during the wet season.

It was also found out that out of the nine micro-organisms identified, seven were commonly present in the river and the reservoir. The two micro-organisms that were not present in the river and the reservoir were *Proteus vulgaris* which was only present in the river and *Escherichia coli* which was only present in the reservoir. This was an indication that the micro-organisms present in the reservoir were not necessarily introduced through the feeder river. This leads to a conclusion that the sources of the micro-organisms in the reservoir and the river are common though for *Escherichia coli* the main receiving body was the reservoir. *Escherichia coli* was found only in the reservoir during the two seasons. *Escherichia coli* is a major indicator of faecal contamination of water. Therefore the findings of this study establish that there is sewage contamination of water in the catchment because *E.*

coli is found only in the mammalian intestinal tract including that of humans (WHO, 2011).

Klebsiella are natural inhabitants of many water environments and they may multiply to high numbers in waters rich in nutrients. Presence of these micro-organisms implies that the water contains nutrients and this explains the high levels of phosphates. *Klebsiella* are excreted in the faeces of many healthy humans and animals and they are readily detected in sewage polluted water.

Pseudomonous aeruginosa can cause a range of infections. It is a common environmental organism and can be found in feaces, soil, water and sewage.

4.4. Causes of Pollution

The causes of degradation of Kiamumbi catchment were established through data collected from the local community through administration of questionnaires and also through photography.

This was mainly focused on finding out the main anthropogenic activities undertaken along the catchment area and also the possible types of pollutants that may be introduced into the water bodies resulting from the activities.

4.4.1: Age of the respondents

The people who responded to the questionnaires were of different ages as presented in appendix A_{10} and figure 4.9 below.

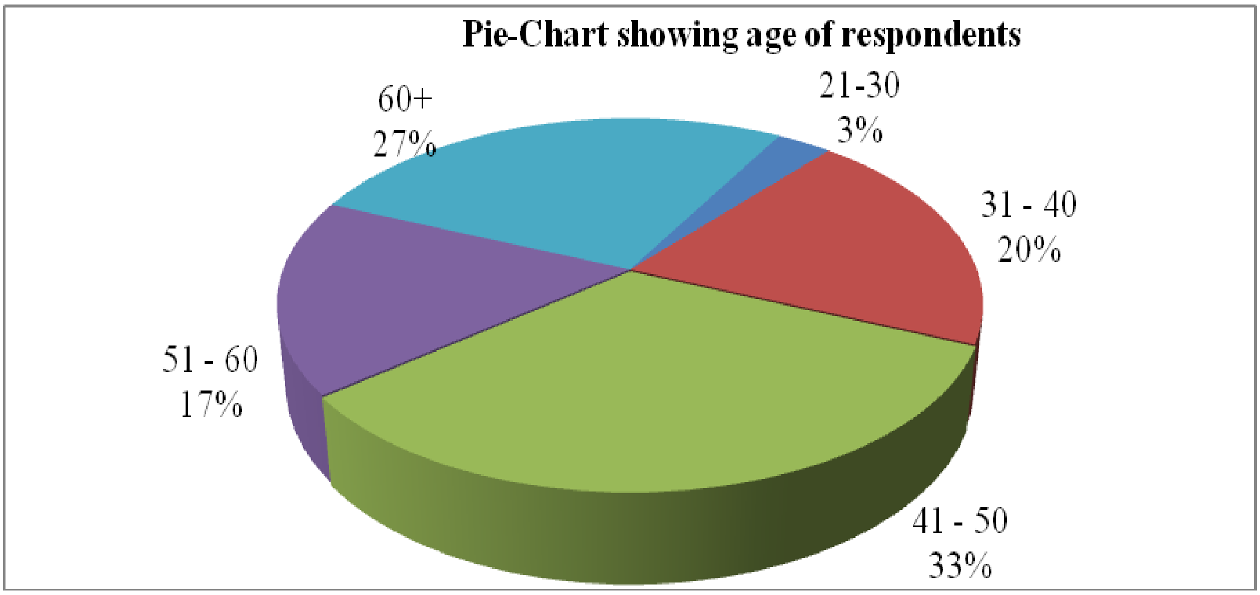


Figure 4.9: Respondents age distribution

33% of the respondents were between the age of 41 to 50 years. This is a high productive age with tendency of contributing to pollution through their anthropogenic activities like farming, quarrying and large families. This group may also produce more waste compared to other age groups. The age group from 60 years and above made was the second largest making 27%. The people who are above 60 years are not very active especially in manual anthropogenic activities hence their contribution to pollution of the catchment cannot equal the latter group.

4.4.2. Education Level of Respondents

The education level of the respondents is as presented in the appendix A_{11} and in figure 4.10 below.

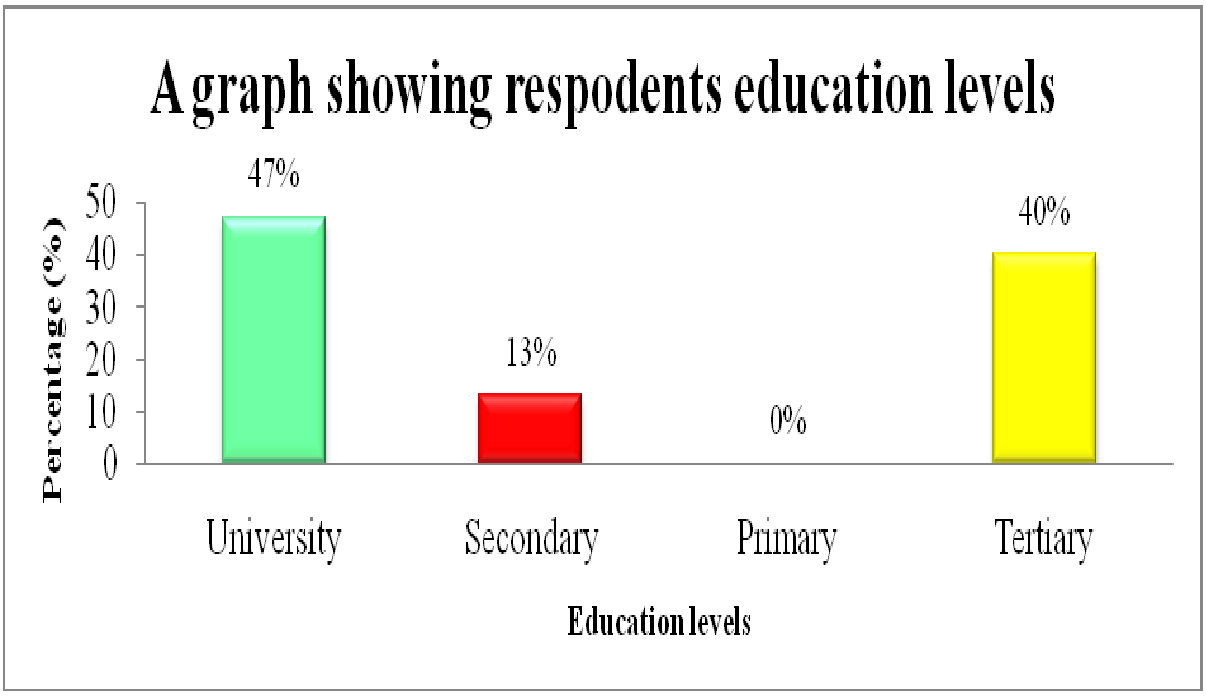


Figure 4.10: Graph showing level of education for respondents

In this study, 47% of the respondents had attained university education while 13% and 40% had acquired secondary education and tertiary education either a college or a technical institute respectively. None of the respondents had studied up to primary level. People with higher level of education are expected to have more knowledge on pollution issues. With the highest number of respondents having university education, it is credible that the information was received from an informed group. On the other hand, people with more education are expected to have more concern on environmental protection.

4.4.3. Number of years spent by the respondents within the catchment

The number of years spent by the respondents within the catchment was as presented in the table 4.14 below. It was important to know the number of years each respondent has been living in this area. This would show that the respondents have a good understanding of the area. On the other hand, the longer the period one has lived in the catchment engaging in anthropogenic activities, it is can be said he has contributed more to pollution of the catchment.

No. of Years	**Percentage (%)**
1 – 3	7
4 – 6	32
7 – 9	19
10 – 12	21
13 – 15	21

Table 4. 4: No of years spent by respondents within the catchment

32% of these respondents had lived within the catchment area for four to six years. 21% of the respondents had lived in this area for ten to twelve years and also for thirteen to fifteen years. One of the common finding among the respondents was that they all knew that the feeder river and the reservoir are polluted.

4.4.4. Activities undertaken along the catchment

The activities undertaken by the local community that would lead to degradation of the catchment were as presented in Figure 4.11 below, as reported by the residents.

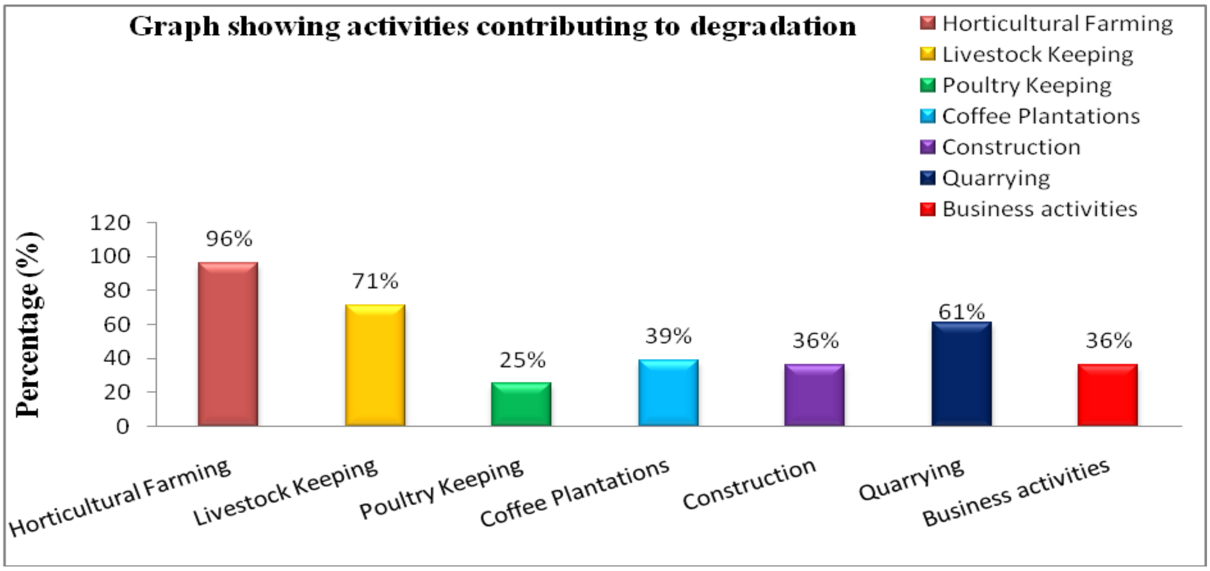


Figure 4.11: Activities contributing to degradation of Kiamumbi Catchment

The respondents were asked to name the activities that are carried out along the Kiamumbi catchment which they think would contribute to degradation of the feeder river and the reservoir.

96% of the respondents blamed degradation of the Kiamumbi catchment on horticultural farming. This is because horticultural farming is known to be accompanied by application of fertilizers, manure and use of pesticides. Plate 4.1, show horticultural farming of kales next to the banks of the feeder river. On the other hand, the crops grown in the polluted catchment may accumulate toxic substances like heavy metals hence impact negatively on human health.

Plate 4. 1: Horticultural Farming along the feeder riverbank

71% of the respondents blamed livestock keeping as a major source of pollution.

Plate 4. 2: Livestock Keeping

During rainy seasons, surface run-off carries dang and food remains from the cattle shed as shown in plate 4.2. into the river and the reservoir. This is a good source of pollutants like *E.Coli*, phosphates and other pollutants like zinc resulting from decay of hay.

61% of the respondents blamed quarrying which result to soil erosion hence increased turbidity which provides a safe haven for micro-organisms and heavy metals from weathering of rocks. An example of quarrying activities is as can be observed in Plate 4.3. below.

Plate 4. 3: Quarrying activities along the catchment

36% blamed construction activities and small business activities equally. In the construction activities, there are solid wastes which are not adequately managed and they are carried into the feeder river and the reservoir. Wastes from the construction sites which include cements and paints are carried into the water bodies by the run-off hence the presence of heavy metals like Lead, Cadmium and Chromium.

Excavated materials like soils are also common in construction sites and when carried away by run-off into the water bodies contribute to high turbidity.

39% reported that coffee farming under the coffee plantations contribute towards degradation. Plate 4.4 shows a section of the coffee plantations within the catchment.

Plate 4. 4: Coffee Plantation along the catchment

In coffee farming, there is extensive use of insecticides and fertilizers which are washed away into the water bodies by run-off and hence the presence of heavy metals, sulphates and phosphates in the water in the catchment. There is an increase in construction of residential houses taking place along the catchment. It was observed that many of the households practice poultry keeping and the excreta from the poultry is carried away into the water bodies in the catchment through run-off hence the presence of salmonella in the water. 25% of the respondents also reported that poultry keeping contributes to degradation of Kiamumbi catchment.

4.4.5. Sources of Pollutants

Figure 4.12 below show the sources of pollutants that were reported by the respondents.

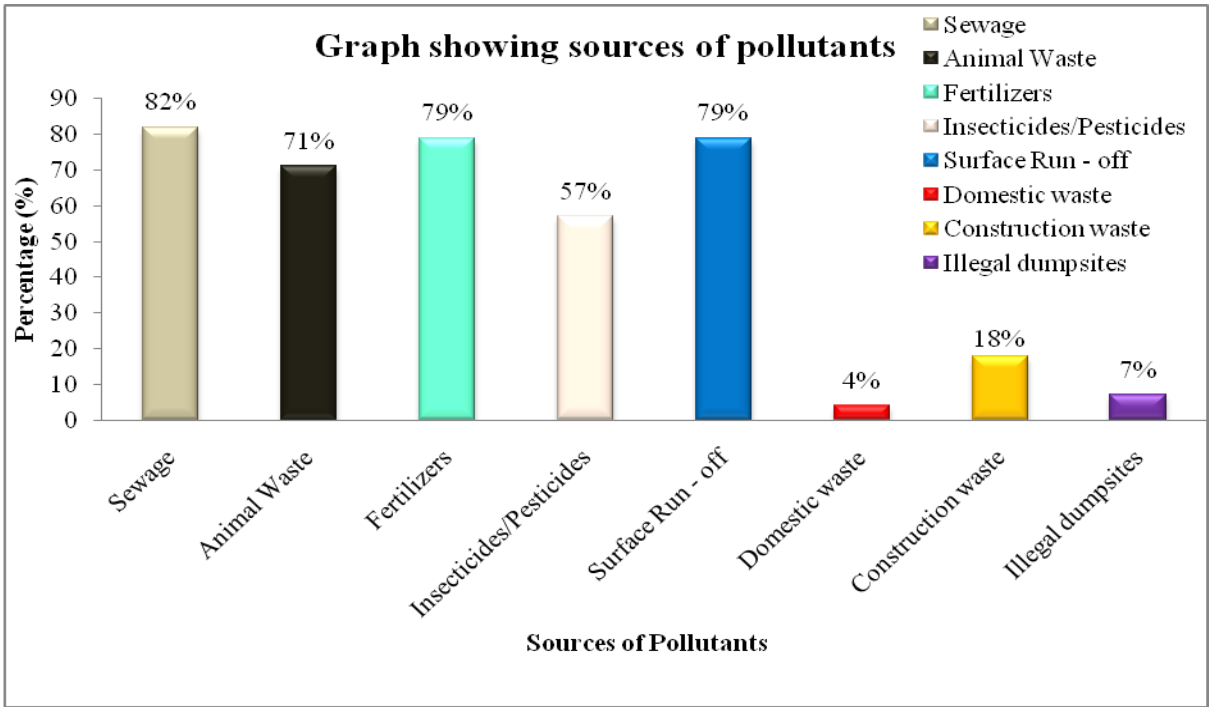


Figure 4.12: Sources of pollutants

The sources of pollutants are presented in Appendices A_{13} and figure 4.12 below as reported by the respondents. From figure 4.12 below, 82% of the respondents blamed sewage as a main source of pollutants. The main sources of sewage include burst sewer lines in urban area like Kiambu and over flowing septic tanks in residences along the catchment. This was followed by 79% of respondents who blamed Fertilizers and surface run-off equally. Within the catchment there are farms where horticultural farming is practiced and this kind of agriculture is known for extensive use of fertilizers. Another source of fertilizers would be coffee plantations and arable farms. 71% and 57% of the respondents felt that animal wastes and

Insecticides/pesticides respectively are major sources of pollutants. There are many households that were observed to keep cattle, poultry and pigs. The waste from these livestock is not properly managed and during rainy season, the surface run-off washes the waste into the feeder river and the reservoir. 18% reported construction waste while 7% reported illegal dumpsites. 4% of the respondents equally blamed domestic waste. In Kiamumbi Estate, there are many construction activities taking place.

The excavated material, paints, cements and other packaging materials can be washed away by run-off. It was observed that along the catchment, there is poor solid waste management. Leachate from illegal dumpsites along the catchment is a major source of pollutants and depending on the kind of waste, this explains a good source of chemical pollutants especially heavy metals. Although, it was not mentioned by any respondent, the other most likely source of pollutants is weathering of rocks and decay of plant remains. This is more possible in the reservoir because it is surrounded by a lot of vegetation. In addition, there is possibility of atmospheric deposition because this catchment is within the circumference of Nairobi where emissions where vehicular and industrial emissions, are likely to fall in the form of acid rain.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0. Conclusion

This study aimed at finding out the quality of water in Kiamumbi catchment through analyzing the bacteriological and Physico-chemical quality of the water. The study also aimed at establishing the causes of degradation of the catchment. The objectives of this study were achieved. In determination of Bacteriological quality of the water in the catchment, nine different micro-organisms were identified in the feeder river and the reservoir. These included *Salmonella, Pseudomonus aeruginosa, Shigella dysentriae, Streptococcus, Escherichia coli, Enterobacter aerogenes, Citrobacter freundii, Klebsiella oxycota* and *Proteus vulgaris.* The micro-organisms were found to be absent in the storage facility hence the water treatment method was found to be very effective on removal of bacteria. The presence of indicator bacteria was an indication of faecal contamination of the catchment.

In determination of the physical chemical quality of the water, it was established that turbidity was above the acceptable levels during the wet season. Other physical parameters that were measured like TDS, EC and pH were within acceptable limits. The heavy metals that were found to have concentration levels beyond recommended standards in both dry and wet season were Chromium with the lowest mean concentration of 0.11 ± 0.07 mg/L at the first sampling point of the feeder river during the wet season, Cadmium with the lowest mean concentration of 0.01 ± 0.013 mg/L recorded at the third sampling point of the river during the dry season, Nickel with the lowest mean concentration of 0.07 ± 0.07 mg/L recorded at the storage facility during wet season, Lead with the lowest mean concentration of 0.05 ± 0.24 mg/L recorded at the third sampling point of the river during the dry season and Iron with the lowest mean concentration of 0.05 ± 0.03 mg/L recorded at the storage facility during the wet season. The other metals which were analyzed which included Copper, Zinc, Magnesium, Manganese and, Calcium existed in trace concentrations.

The main sources of chemical pollutants in Kiamumbi catchment were found to be fertilizers, insecticides/ pesticides, surface run-off, domestic waste, construction waste and illegal dumpsites. However, other likely sources include natural geophysical processes like weathering of rocks and atmospheric deposition though acid rain. Anthropogenic activities like Horticultural farming, Livestock keeping, poultry keeping, coffee plantations, construction, Quarrying and business activities are the main contributors of degradation of the catchment although natural geophysical processes like weathering of rocks cannot be overlooked.

From the findings, the concentration of the chemical pollutants was not reduced after treatment in reference to levels obtained from the storage facility. This was a clear indication that the water treatment method was not effective in removal of inorganic pollutants. This renders the water unfit for human consumption. Continued consumption of the water supplied by KWT in Kiamumbi Estate may in the future result into serious human health impacts because after treatment, the water still showed presence of chromium, Cadmium, Lead, Iron and Nickel which have varied human health impacts. The objectives of this study were achieved because results obtained indicate that the catchment is polluted by both biological and physic-chemical pollutants. In addition, through the local communities, different sources of pollutants were identified.

6.0 Recommendation

In reference to the findings of this study, there are issues that should be addressed and put in place measures to reverse the pollution status of Kiamumbi catchment. This study recommends implementation of the following strategies to address the wanting quality of the water in Kiamumbi catchment.

i. The water treatment method should be improved for example by introducing chemical oxidation to lower concentration of inorganic pollutants to acceptable levels. KWT should adopt Integrated Water Resources Management (IWRM) approach.

ii. Creation of awareness among the community living within the catchment to stop activities leading to pollution of the catchment for example proper waste disposal and adoption of organic farming to curb excessive use of chemicals and fertilizers.

iii. Regulatory Authorities should be encouraged to carry out random water quality analysis of such critical water sources to protect innocent consumers of such highly polluted water.

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APPENDICES:

Appendix A_1: Table for determining Minimum Returned Sample Size for a given Population Size for Continuous and Category Data

Population Size	Sample Size					
	Continuous Data (Margin of error = .03			Categorical Data (Margin of error =.05		
	alpha =.10 t=1.65	alpha =.05 t =1.95	alpha =.01 t =2.58	P =.50 t =1.65	P =.50 t =1.96	P =.50 t =2.58
100	46	55	68	74	80	87
200	59	75	102	116	132	154
300	65	85	123	143	169	207
400	69	92	137	162	196	250
500	72	96	147	176	218	286
600	73	100	155	187	235	316
700	75	102	161	196	249	341
800	76	104	166	203	260	363
900	76	105	170	209	270	382
1000	77	106	173	213	278	399
1500	79	110	183	230	306	461
2000	83	112	189	239	323	499
4000	83	119	198	254	351	570
6000	83	119	209	259	362	598
8000	83	119	209	262	367	613
10000	83	119	209	264	370	623

NOTE: The margins of error used in the table were .03 for continuous data and .05 for categorical data. Researchers may use this table if the margin of error shown is appropriate for their study: however, the appropriate sample size must be calculated if these error rates are not appropriate. Table developed by Bartlett, Kotrlik, & Higgins.

Appendix A_2: Mean Value of Turbidity (NTU)

Sampling point	Wet Season		Dry Season	
	Range	$\bar{x}$ ±Stdev	Range	$\bar{x}$ ±Stdev
RS 1	13.6-17.7	15.8±2.07	0.7-3.2	2.3±1.42
RS 2	19.5-21.1	20.5±0.85	0.6-1.1	0.9±0.3
RS 3	18-21.8	19.6±2	0-1.2	0.8±0.7
RSV	14.7-27.2	19.25±4.22	0.1-1	0.083±0.04
SF	0-0.11	0.17±0.64	0	0
RSTD		**5**		**5**

Appendix A_3: Mean pH values.

Sampling Point	Wet Season		Dry Season	
	Range	$\bar{x}$ **±Stdev**	**Range**	$\bar{x}$ **±Stdev**
RS1	7.05 - 7.17	7.11 ±0.06	7.01 - 7.22	7.12 ±0.11
RS2	7.15 - 7.23	7.19 ±0.04	6.96 - 7.09	7.03 ±0.07
RS 3	7.17 - 7.27	7.24 ±0.06	6.88 - 7.05	6.96 ±0.09
RSV	7.01 - 7.32	7.2 ±0.01	6.90 - 7.37	7.09 ±0.14
SF	7.25 - 7.38	7.3 ±0.07	7.0 - 7.07	7.03 ±0.04
RSTD		**6.5 - 8.5**		**6.5 – 8-5**

Appendix A_4: Mean Value of Total Dissolved Solids (mg/L).

Sampling Point	**Wet Season**		**Dry Season**	
	Range	$\bar{x}$ **±Stdev**	**Range**	$\bar{x}$ **±Stdev**
RS 1	158.1 - 182.2	166.2 ± 13.86	91.6 - 95.6	93.2 ± 2.14
RS 2	107.3 - 154.4	154.1 ± 0.36	107.3 - 111.2	108.9 ± 2.04
RS 3	115.3 - 119.2	116.9 ± 2.06	105.5 - 107	106.4 ± 0.8
RSV	112.5 - 137.3	119.6 ± 6.57	110.8 - 117.8	113.4 ± 2.15
SF	233 - 187	217.3 ± 21.5	179 - 182	180.7 ± 1.53
RSTD		**1000**		**1000**

Appendix A_5: Mean Value of electrical Conductivity (μS)

Sampling Point	**Wet Season**		**Dry Season**	
	Range	$\bar{x}$ **±Stdev**	**Range**	$\bar{x}$ **±Stdev**
RS 1	0.24 – 0.27	0.25±0.02	0.15- 0.16	0.15±0.006
RS 2	0.23 – 0.25	0.24±0.01	0.16 – 0.17	0.16±0.006
RS 3	0.18 – 0.19	0.19±0.006	0.03 – 0.03	0.03±0
RSV	0.03 – 0.21	0.16±0.077	0.16 – 0.2	0.18±0.01
SF	0.28 – 0.32	0.3±0.02	0.28 – 0.28	0.28±0.05
RSTD		**0.05**		**0.05**

Appendix A_6: Heavy Metals concentration during the wet seasons

Sampling Point		**Zn**	**Cr**	**Cu**	**Ca**	**Mg**	**Mn**	**Cd**	**Ni**	**Pb**	**Fe**
RS1	Range	0.01-0.17	0-0.13	0.08-0.1	0.13-1.45	0.8-1.46	0-0.21	0-0.03	0.02-0.2	0-0.39	0.36-0.6
	Mean	0.1	0.11	0.1	0.84	1.21	0.18	0.03	0.09	0.37	0.5
	Stdev	±0.08	±0.07	±0.04	±0.67	±0.36	±0.11	±0.02	±0.07	±0.22	±0.12
RS2	Range	0.03-0.15	0-0.66	0.04-0.25	1.18-5.56	0.74-1.34	0.03-0.21	0.01-0.02	0-0.31	0.56-2.2	0.49-0.6
	Mean	0.1	0.32	0.1	2.84	0.96	0.12	0.02	0.25	1.3	0.5
	Stdev	±0.06	±0.33	±0.12	±2.38	±0.32	±0.09	±0.01	±0.16	±0.83	±0.05
RS3	Range	0.06-0.21	0.12-0.51	0-0.14	2.35-3.83	2.06-2.23	0-0.31	0.02-0.04	0-0.27	0-0.22	0.31-0.5
	Mean	0.15	0.27	0.1	3.06	2.15	0.17	0.03	0.2	0.22	0.42
	Stdev	±0.08	±0.21	±0.08	±0.74	±0.09	±0.17	±0.01	±0.13	±0.13	±0.10
RSV	Range	0.01-0.6	0.08-1.0	0.01-0.17	0.81-2.42	1.25-1.65	0-0.34	0.01-0.05	0-0.72	0-0.76	0.34-0.7
	Mean	0.16	0.44	0.1	1.69	1.43	0.18	0.02	0.31	0.43	0.56
	Stdev	±0.15	±0.55	±0.05	±0.5	±0.13	±0.14	±0.02	±0.24	±0.29	±0.29
SF	Range	1.07-1.21	0.23-1.66	0.02-0.11	2.33-3.22	1.82-1.99	0.05-0.28	0.01-0.02	0-0.13	0.33-0.9	0-0.06
	Mean	0.82	0.83	0.1	2.78	1.92	0.13	0.02	0.07	0.59	0.05
	Stdev	±0.55	±0.75	±0.55	±0.5	±0.89	±0.13	±0.01	±0.07	±0.27	±0.03
	RSTD	**5**	**0.05**	**1**	**150**	**100**	**0.5**	**0.003**	**0.02**	**0.01**	**0.3**

Appendix A_7: Heavy Metals concentration during the dry seasons

Sampling Point		**Zn**	**Cr**	**Cu**	**Ca**	**Mg**	**Mn**	**Cd**	**Ni**	**Pb**	**Fe**
RS1	Range	0-0.012	0-0.38	0-0.02	0.08-0.15	5.38-6.00	0.052-0.14	0-0.049	0.23-0.4	0	0.83-1
	Mean	0.004	0.3	0.02	0.75	14.1	0.29	0.03	0.31	0.23	0.72
	Stdev	±0.001	±0.22	±0.009	±0.037	±0.31	±0.05	±0.026	±0.06	±0	±0.18
RS2	Range	0-0.004	0.43-1.08	0-0.02	0.25-0.29	2.99-8.63	0.118-0.37	0-0.013	0-0.24	0-0.07	0.25-0.8
	Mean	0.012	0.38	0.02	0.12	5.67	0.09	0.04	0.29	0	0.8
	Stdev	±0.002	±0.34	±0.008	±0.022	±3.07	±0.13	±0.007	±0.14	±0.04	±0.26
RS3	Range	0-0.004	0.23-1.57	0-0.01	0.24-0.32	7.93-8.58	0.13-0.5	0-0.026	0.5-0.1	0.27-0.7	0.25-0.9
	Mean	0.003	0.71	0.02	0.27	6.51	0.26	0.01	0.24	0.05	0.53
	Stdev	±0.002	±0.68	±0.007	±0.041	±0.41	±0.21	±0.013	±0.26	±0.24	±0.3
RSV	Range	0-0.009	0-3.41	0-0.02	0.27-0.45	8.53-9.63	0.03-0.16	0-0.63	0-1.34	0-064	0.02-0.7
	Mean	0.004	0.94	0.01	0.27	8.11	0.26	0.02	0.3	0.43	0.55
	Stdev	±0.004	±1.08	±0.01	±0.05	±0.36	±0.1	±0.02	±0.38	±0.21	±0.21
SF	Range	0.001-0.01	0-0.31	0.01-0.02	0.68-0.81	13.7-14.6	0.2-03	0.004-0.06	0-0.031	0.1-0.3	0.05-0.2
	Mean	0.007	1.4	0.01	0.35	8.91	0.2	0.03	0.47	0.36	0.41
	Stdev	±0.003	±0.17	±0.01	±0.07	±0.46	±0.078	±0.032	±0.18	±0.13	±0.07
	RSTD	**5**	**0.05**	**1**	**150**	**100**	**0.5**	**0.003**	**0.02**	**0.01**	**0.3**

Appendix A_8: Mean Concentration of Phosphates during wet and dry seasons

Sampling Points	**Wet Season**		**Dry Season**	
	Range	**$\bar{x}$ ±Stdev**	**Range**	**$\bar{x}$ ±Stdev**
RS1	7.33 – 13.36	11±3.25	15.94 – 16.62	10.5±0.34
RS2	10.69 – 14.42	12.2±1.97	14.05 – 19.49	16.3±0.86
RS3	11.44 – 15.35	13.5±1.97	15.18 – 19.64	17±1.21
RSV	6.95 – 17.96	11.1±3.5	2.76 – 17.98	17.6±4.27
SF	5.28 – 9.94	8.31±2.62	8.76 – 12.46	11.7±1.86
RSTD		**2.2**		**2.2**

Appendix A_9: Mean concentrations of Sulphate during wet and dry seasons.

Sampling points	**Wet Season**		**Dry Season**	
	Range	**$\bar{x}$ ±Stdev**	**Range**	**$\bar{x}$ ±Stdev**
RS1	0 – 0.5	0.3±0.23	0.5 – 0.52	0.7±0.01
RS2	0.3 – 0.4	0.4±0.03	0.51 – 0.62	0.51±0.06
RS3	0.4 – 0.4	0.4±0.03	0.49 – 0.62	0.57±0.08
RSV	0.1 – 0.5	0.43±0.11	0.31 – 1.3	0.57±0.27
SF	0.1 – 0.6	0.3±0.27	0.66 – 0.77	0.51±0.06
RSTD		**400**		**400**

Appendix A_{10}: Respondents age distribution

Age group(Yrs)	**Percentage (%)**
21-30	3%
31 – 40	20%
41 – 50	33%
51 – 60	17%
60+	27%

Appendix A_{11}: Respondents Education Level

Level of education	**Percentage %**
University	47
Secondary	13
Primary	0
Tertiary	40

Appendix A_{12}: Activities contributing to degradation of the catchment

Activity	**% of Respondents**
Horticultural Farming	96
Livestock Keeping	71
Poultry Keeping	25
Coffee Plantations	39
Construction	36
Quarrying	61
Business activities	36

Appendix A_{13}: Sources of pollutants

Source	**% of Respondents**
Sewage	82
Animal Waste	71
Fertilizers	79
Insecticides/Pesticides	57
Surface Run - off	79
Domestic waste	4
Construction waste	18
Illegal dumpsites	7

Appendix A_{14}: Number of Tubes giving Positive Reaction out of 3 during wet season

Sampling point	Sample Code	3 of 10ml each	3 of 1 ml each	3 of 0.1 ml each	MPN Index per 100ml
SF	1	0	0	0	0
“	2	0	0	0	0
“	3	0	0	0	0
RSV sp1	4	3	3	3	>1,100
“	5	3	2	1	150
“	6	3	3	3	>1,100
RSV sp2	7	3	3	3	>1,100
“	8	3	3	3	>1,100
“	9	3	3	3	>1,100
RSVsp3	10	3	3	3	>1,100
“	11	3	3	3	>1,100
“	12	3	3	3	>1,100
RSV sp4	13	3	3	3	>1,100
“	14	3	3	3	>1,100
“	15	3	3	3	>1,100
RS 1	16	3	3	3	>1,100
“	17	3	3	3	>1,100
“	18	3	3	3	>1,100
RS 2	19	3	3	3	>1,100
“	20	3	3	3	>1,100
“	21	3	3	3	>1,100
RS3	22	3	3	3	>1,100
“	23	3	3	3	>1,100
“	24	3	3	3	>1,100

Appendix A_{15}: Number of Tubes giving Positive Reaction out of 3 during dry season (MPN)

Sampling point	Sample	3 Tubes of 10mls	3 Tubes of 1 ml	3 Tubes of 0.1 ml	MPN Index
RSV sp 1	1	3	3	3	>1100
“	2	3	3	3	>1100
“	3	3	3	3	>1100
RSV sp 2	4	3	3	3	>1100
“	5	3	3	3	>1100
“	6	3	3	3	>1100
RSV sp 3	7	3	3	3	>1100
“	8	3	3	3	>1100
“	9	3	3	3	>1100
RSV sp 4	10	3	3	3	>1100
“	11	3	3	3	>1100
“	12	3	3	3	>1100
SF	13	0	0	0	0
“	14	0	0	0	0
“	15	0	0	0	0
RS 1	16	3	3	3	>1100
“	17	3	3	3	>1100
“	18	3	3	3	>1100
RS2	19	3	3	3	>1100
“	20	3	3	3	>1100
“	21	3	3	3	>1100
RS3	22	3	3	3	>1100
“	23	3	3	3	>1100
“	24	3	3	3	>1100

Appendix A_{16}: Procedure for Presumptive Test for Bacteriological Analysis

Materials required; 3 Durham tubes of DSLB, 6 Durham tubes of SSLB, 1 10ML pipette, 1 1ml pipette, Lactose Broth, Disposable petri dishes,Universal bottles, Nutrients agar and Eosin Methane blue agar.

Procedure

i. All apparatus were sterilized.

ii. Mac Cockey Broth (medium) was prepared in Double Strength and Single Strength.

The double strength MacConkey Broth was prepared by dissolving 70g/L of the powder in 1.0litre of distilled water while single strength was prepared by dissolving 35g/L in1.0 Litre of distilled water.

iii. The medium was sterilized at 121ºc in an autoclave machine.

iv. Three sets of three universal bottles were prepared. One set was DSLB and two sets were SSLB.

v. Each bottle was filled with 10mls of the medium.

vi. The bottles were labeled according to the amount of sampled water that was to be dispensed in each. (10ml, 1ml and 0.1 ml) respectively

vii. The water samples were shaken to ensure even distribution of micro-organisms.

viii. With a 10ml pipette, 10mls of water were transferred to each of the DSLB.

ix. With a 1.0ml pipette, 1.0ml of water were transferred to each of the three bottles of SSLB.

x. 0.1mls were transferred to each of the last three bottles of SSLB.

xi. The bottles were then incubated for 24hrs at 37^{o}c.

xii. After 24 hrs, the bottles were checked and results recorded as in table 9 and 10

Appendix A_{17}: Manufacturer's Directions for Bio-chemical Tests Mediums

1. MR –VP Medium (Buffered Glucose Broth)(Glucose Phosphate Broth)

This is for performance of Methyl Red and Voges – Proskauer tests in differentiation of coli-aerogenes group. Suspend 17.0 grams in 1000ml distilled water. Heat if necessary to dissolve the medium completely. Distribute in test tubes in 10ml amounts and sterilize by autoclaving at 15 ibs pressure (121^{o}c) for 15 minutes.

2. Urea Broth Base

This is a differential medium for the detection of rapid urease production by micro-organisms. Weigh 0.9grams of powder, add to 95mls of de-ionized water. Swirl to mix then sterilize by autoclaving at 121^{o}c for 15 minutes. Allow to cool to 48^{o}c then add aseptically 5mls of x130 sterile urea solution. Distribute into sterile screw cap bi jou bottles.

3. Nitrate Agar

Recommended for detection of nitrate reduction by bacteria. Suspend 21 grams in 100ml. distilled water. Boil to dissolve the medium completely. Dispense in tubes and sterilize by autoclaving at 15ibs pressure (121^{o}c) for 15minutes. Allow to cool the tubes in a slanted position.

4. SIM Medium

This is recommended for determination of hydrogen Sulphide production, Indole formation and motility of enteric bacilli. Suspend 36.23 grams in 1000ml distilled water. Heat to boiling to dissolve the medium completely. Dispense in tubes.

Sterilize by autoclaving at 15ibs pressure (121^{o}c) for 15minutes. Allow the tubes to cool in an upright position.

5. Simmons Citrate Medium

This is a solid medium for verifying the citrate utilization by enterobacteria. Dissolve 24 grams of powder in 1 litre of distilled water. Bring to the boil. Dispense in tubes and sterilize by autoclaving at 15ibs pressure (121^{o}c) for 15minutes. Solidify with long slant.

6. **Tripple Sugar Iron Agar**

This was used to determine the ability of the micro-organisms to attack carbohydrate. Suspend 65 grams in 1 litre of distilled water. Bring to the boil to dissolve completely. Mix well and distribute into containers. Sterilize by autoclaving at121^{o}c for 15minutes. Allow to set as slopes with 2.5cm butts.

7. Tryptone Water (Peptone Water)

This is a substrate with low nutrients capacity, for the research of indole production in coliform micro-organism. Dissolve 15grams in 1 litre of distilled water and dispense into suitable containers. Sterilize by autoclaving at 121^{o}c for 15minutes.

Appendix A_{18}: Procedure for determination of Chloride using Spectrophotometry

The method is based on the formation of the characteristic iron (III) thiocyanate colour, when chloride ion reacts with mercury (II) thiocyanate in the presence of iron (III) ions.

a. Preparation of reagents

i. Alcoholic mercury (II) thiocyanate: 0.030g of mercury (II) thiocyanate were dissolved in 100ml. of industrial methylated spirit in a 250Ml. conical flask, and warmed gently to assist solution. The resulting solution was stored in a glass stoppered reagent bottle.

ii. Ferric alum solution: 6.0G of ferric alum were dissolved in100Ml of 6M nitric acid. The solution was stored in a 250Ml glass reagent bottle.

iii. Standard stock solution of chloride ion: 1000ppm Cl^- ion in double deionised water was made up using analar grade sodium chloride as a source of Cl^- ion.

iv. Working solutions for chloride ion (0 – 100ppm): By dilution of an aliquot of the 1000ppm standard stock solution with double deionised water, 250Ml Cl^- solution was prepared. The latter solution was used to prepare50ml of standard working solutions containing 15, 20, 40, 60 and 80ppm of Cl^- ion respectively.

b. Preparation of reagent blank:

10ml of double deionised water was added to a 100ml beaker. 2.0ml of ferric alum solution and 1.0mL of alcoholic mercury thiocyanate solution were added. After ten minutes the reagent blank was ready for use in reference beam of the spectrophotometer.

c. Determination of absorption spectrum of ion (IIF) thiocyanate.

10mL of a 50 ppm solution of Cl^- was added into a 100ml beaker after which 2.0ml of ferric alum and 1.0mL of thiocyanate reagent were added. Using 1cm cell, an absorption spectrum of the iron(III) thiocyanate complex was obtained with the SP 8000 Spectrophotometer set on 0-1.0 Absorbance range, slow scan setting and a wavelength range of 430 – 850mm.

d. Preparation of calibration curve

10 ml of each of the working standard solutions ranging from 15 – 100 ppm Cl^- was added into separate 100ml beakers. To each solution 2.0ml of ferric alum solution was added followed by 1.0ml of Mercury (II) thiocyanate and then the absorbance of each solution of 470mm was was measured using a 1 cm cell, against a reagent blank in the reference beam. A curve was plotted of absorbance against ppm of Cl^- and the linear part of the curve was indicated.

e. Determination of Cl^- in water samples

This was done by using a 10ml aliquot of water samples and adding the reagents as indicated above and then determined the absorbance of each solution. Using the calibration graph, the concentration of Cl^- in ppm was determined in each water sample,

Appendix A_{19}: Procedure for Determination of Sulphate using Spectrophotometry Method

a. Reagents:

Standard Sulphate Solution. Dissolve 1.814g dry AR. Potassium sulphate in distilled water and dilute to 1 dm3 in a graduated flask. This solution contains 1.000mg of sulphate ion per cm3.

Sodium chloride- hydrochloric acid reagent: Dissolve 60g A.R. sodium chloride in $200cm^3$ distilled water, add $5cm^3$ pure concentrated hydrochloric acid, and dilute to $250cm^3$.

Barium chloride: Use crystals of A.R. barium chloride that pass through a 20-mesh sieve and are retained by a 30-mesh sieve.

Glycerol-ethanol solution: Dissolve 1 volume of pure glycerol in 2 volume of absolute ethanol.

b. Procedure

Run 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 cm^3 of the standard potassium sulphate solution from a calibrated burette into separate $100cm^3$ graduated flask.

To each flask add $10cm^3$ of the sodium chloride-hydrochloric acid reagent and $20cm^3$ of the glycerol-ethanol solution, and dilute to $100cm^3$ with dilute water.

Add 0.3g of the sieved barium chloride to each flask, and shake for 1 minute by inverting each flask once per second:all the barium chloride should dissolve. Allow each flask to stand for 2-3 minutes and measure the turbidity in the Nephelometer:

Use the most concentrated solution as standard and, by means of the sensitivity control, adjust the galvanometer reading to 100 divisions.

Prepare a ‘blank’ solution, repeat the above sequence of operations, but do not add any sulphate solution.

Place the ‘blank’ solution in the nephelometer and adjust to zero reading of the galvanometer scale by means of the zero control above the galvanometer suspension.

Check the reading of the most turbid solution, and adjust any deviation from 100 by means of the sensitivity control. Repeat the measurements with the five other standard sulphate solutions.

Plot the galvanometer reading against the sulphate –ion content per $cm^{3.}$

Appendix A_{20}: Procedure for Determination of Phosphate using Spectrophotometry Method

Involves conversion of phosphate to molybdenum blue whose colour is monitored spectrophotometrically at 660mm.

Reagents required

1) Ammonium molybdate (0.005). Dissolve 6.1793g of ammonium heptamolybdate. $4H_2O$ in 11 of 0.4m nitric acid.

2) Ascorbic acid (0.7% w/w). Dissolve 7.0000g of ascorbic acid in 11 of water and add 10ml of glycerine.

3) Phosphate stock solution (10mg/L. Dissolve 0.439g of potassium dihyrogen phosphate in 11 of water.

Dilute the above phosphate stock solution with distilled water to prepare solution with

distilled water to prepare solutions containing 1.5mg/ml phosphorous as phosphate.

Colour formation and measurement

Add 3ml of molybdate to 3.0 ml of ascorbic acid solution in a 50 ml volumetric flask. Shake to mix and add 10 ml of sample. Add distilled water to the mark. Mix well and allow to stand 10 – 15 minutes. Then measure the absorbance at 660mm.

Use method to find the amount of phosphate in the water samples provided.

i. Measure the absorbance of each standard and samples at least three times, and calculate the mean absorbance for each.

ii. Plot mean absorbance vs phosphorous concentration and use it to calculate the phosphorous concentration in the samples provided.

Appendix A21: Questionnaire

Jeremia Wahome is a student at JKUAT undertaking a Masters Degree in Environmental Legislation and with permission from Kiamumbi Reservoir Water Project Board of Management is undertaking a research on Bacteriological and Physico-chemical quality of Kiamumbi Catchment. This questionnaire is meant to gather relevant information that will help in achieving set objectives in this research. All the information you give will be treated with utmost confidentiality.

1. What do you do for a living?

2. What is your highest level of education?

3. Do you know Kiamumbi Reservoir and the river that feeds it? Yes

No

4. (a) In your own Opinion, is the Reservoir and the river Polluted? Yes

No.

(b) If ‘Yes’ what would you say are the sources of pollution?

5. What are the main economic activities undertaken along Kiu River and next to Kiamumbi

Reservoir?

6. Which economic activities do you undertake in your farm?

7. (a) Do you use any chemicals, fertilizers, pesticides or insecticides in your farm?

Yes No

(b) If ‘Yes’ Name them or explain?

8. Do you use a pit latrine or a septic tank?

9. If you use a septic tank, is it connected to a soak pit and after how long do you exhaust it?

Appendix A_{22}: Determination of Physical and Chemical quality of water in Kiamumbi Catchment Journal of Biodiversity and Environmental Sciences (JBES) Vol.4, No. 1, p. 24 – 33, 2014