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QUALITY ASSESSMENT OF RAIN AND STORM WATER RUNOFF FOR NAIROBI CITY INDUSTRIAL AND SUB-URBAN AREAS

By

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I declare that this is my original work and has not been presented for a degree in any other University

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DEDICATION

I humbly dedicate this work to my wife Loise, children, Faith, Joy, Ernest and Patience as an expression of gratitude for their continued support and encouragement to pursue my academic interests.

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ABSTRACT

Nairobi like most cities in the world is faced with water shortages because all the surface water sources have been tapped and the ground water overexploited, yet the water demand continues to rise as the population grows. The city must therefore seek alternative means of water supply. One of the promising sources is rainwater harvesting, which has successfully been adopted to supply water in many other cities. However, there is a concern about the quality of the rainwater falling through a heavily industrialized city atmosphere and flowing over polluted grounds. There is need to determine the quality of rainwater and the resulting storm water so as to make a decision on the best application or treatment of the water. The purpose of the study was therefore to determine the physical and chemical properties of rain and storm water runoff in sub-urban and industrial settings in Nairobi. Two sites were identified namely Upper Kabete Campus (heavily vegetated agricultural suburb), and Jomo Kenyatta International Airport (heavily industrialized area of the city) to assess the water quality of rainwater received and storm water runoff exiting to drains. Water samples were collected directly from falling rain and also from runoff water at the sites for laboratory analysis. The samples were analyzed for water quality parameters namely pH, alkalinity, hardness, total dissolved solids, chlorides, calcium, nitrates, iron. The results from the two sites were compared statistically. It was found that the quality of rain water does not differ significantly in physiochemical parameters at 0.05 significant levels between the sub-urban and industrial setting. The falling rainwater was only slightly above the WHO requirements and required only modest treatment while the storm water was significantly above the WHO limits and either need treatment or may be used for non-potable application. Results of the study are useful in addressing challenges of water quality partly by encouraging use of rain and storm water for non-portable uses and preserving the limited treated water for essential household uses

CHAPTER ONE: INTRODUCTION

1.1 Background

The territory of Nairobi is around 700 km^2 and at an elevation ranging between 1 600 to 1 850 m above ocean level and has great climate with fair temperatures (CBS 2001, Mitullah 2003). The western of Nairobi is at most notable height, with a tough geography, while the eastern side is at the least elevation and for the most part level. The Nairobi, Ngong, and Mathare streams navigate over a few territories and the indigenous Karura backwoods goes over the northern Nairobi. The Ngong slopes are near the city westwards while Mount Kenya rises facilitate away in the north (Olima 2001). The vast majority of Nairobi's urban impression is spontaneous settlement as a consequence of quick populace increment and urban neediness, among different factors.

Water in the greater part of the Nairobi River sub-basins was observed to be exceedingly contaminated by research findings did by Africa Water Network in 2001. Hence, critical measures are required to mitigate the significant issues inside these sub-basins. Effects that demonstrate clean treated water is not accessible has been manifested by rising cases of water related illnesses in the City to be specific cholera, typhoid and so forth. In spite of numerous innovative advances being developed, establishing of safe water inside sensible expanse from property has remained a problem.

Disregarding the affliction experienced therefore of water unavailability a significant part of the rain water is not harvested but escapes into streams and underground (Mulei and Ongwenyi, 1992).

Water is basic to all types of life and between 50-97% of the heaviness of all plants and creatures and around 70% of human body (Allan, 1995).

It is likewise a crucial asset for agribusiness, processing assemblies, transportation and a few human exercises. Despite its significance, is among the most ineffectively managed resources on the planet (Chutter, 1998). The nature of this resource is firmly connected to its utilization and to the level of monetary headway (Chennakrishnan et al., 2008). Pollution of ground and surface waters could be brought on by a few sources. In urban areas, the improper dumping of industrial effluents and different wastes could enormously bargain the natural eminence of water (Mathuthu et al., 1997). It has been noticed that the water bodies in many localities especially in 3rd world countries are the dumping purposes of effluents released from businesses.

The water in a raindrop already used to be one of the cleanest fountains of water accessible, however because of environmental contamination from hotspots for example autos, enterprises, emanations from residential utilization of charcoal as well as kindling, and different sources like the open incineration of metropolitan waste, has changed the situation fundamentally. Air contamination antagonistically influences the nature of water inside the city which influences human wellbeing and the earth. Storm water spillover comes to realization after precipitation and the water from rain streams over land or impenetrable surfaces, for example, cleared avenues, parking areas and housetops and does not permeate into the ground. The overflow water amasses and transports chemicals, supplements, contamination buildups and flotsam and jetsam which can unfavorably influence water quality on the off chance that it is released without first being treated.

The study therefore intends to determine the various water quality parameters for falling rain and runoff in two different settings and compare the extent of variation of corresponding values of the said parameters for the two different settings.

1.2 Problem statement and justification

There is a growth in demand that exceeds the supply of the water resource. The rate of growth of demand for water is higher than population growth as income levels of urban dwellers increase and the assertions for improved services rise. The water availability is also dwindling as a result of contending demands from other economic sectors namely; agriculture, mining, and manufacturing and from deteriorating water quality and climate change. Nairobi is also in the glare of flood hazards due to an unplanned development blocking drainages, poor solid waste and wastewater management issues.

Good water quality is a fundamental human right vital to the health and well-being of the population. Adequate water quality occurs when: the water resource is free of bacteria of faecal origin which may cause diarrhoea and other water borne diseases (e.g. typhoid fever): the levels of chemicals compounds in the water (e.g. heavy metals) are within tolerable levels: water is free of bad taste and odor.

To safeguard human health, the water sources need to be protected from pollution and to reduce costs of water treatment. With Nairobi's population expected to upsurge past the five million mark the estimated demand for water in the City in 2020 and 2030 stands at 1.6 million and 2.2 million cubic metres respectively. As the city continues to grow both in population and the physical extent, demand for water has over stripped supply.

1.3 Overall objective

The overall objective is to determine and compare the quality parameters of falling rainwater and storm water runoff for an industrial and peri urban setting.

1.4 Specific objectives.

The specific objectives of the study were as follows:

1. Determine quality parameters of falling rainwater and runoff.
2. Compare quality parameters between peri-urban and industrial setting.

CHAPTER TWO: LITERATURE REVIEW

2.1 Concepts of water quality and monitoring.

The term quality with respect to water is utilized to mark the condition or natural soundness of a water asset that aids both human and untamed life. The water quality account criteria characterizes, as opposed to measuring, the earth and achievable objectives that must be maintained to bolster an assigned utilize. The criteria sets up a positive articulation about oceanic attributes anticipated to happen in a water body, and they may likewise characterize the condition that are coveted in a water body (National Research Council, 1993).

Checking water quality includes measuring the degrees that create measurements on conditions and enable researchers and managers to gauge patterns. Observing make accessible the information required for the appraisal of the earth of the water in connection to the normal changeability, human impacts and anticipated uses (Chapman, 1992). In spite of the fact that an evaluation is a total appraisal of general strategy, it is demanding to decide the majority of the properties of a water body; physical, synthetic and organic. In the appraisal, a couple of factors are chosen keeping in mind the end goal to give general signs of ecological conditions (Robertson and Davis 1993).

2.2 Effects of urban Agriculture on water quality

The act of urban cultivating includes developing, handling, and circulating food in or adjacent a town, town, or city. It includes domesticated animals rearing, aquaculture, agro ranger service, honey bee keeping, and cultivation which could bring about agrarian contamination. The result would be obliteration of the earth and encompassing biological systems, harm to people and their financial advantages.

The sullying radiate from different sources; from guide sources toward more diffuse, scene level causes, referred to as non-point source toxins (Gullan and Cranston, 2010). Administration practices are an immediate capacity of the amount and effect of these contaminations. Administration hones shift from animal and housing administration, the utilization of pesticides and application manures, fertilizers. (USEPA 2013).

2.2.1 Leaching, runoff, and eutrophication

Utilization of nitrogen (N) and phosphorus (P) to agrarian land through engineered composts, fertilizers, excrements, bio solids, gives profitable plant supplements. In any case, the overabundance N and P can have undesirable natural outcomes. Overabundance N from both manufactured and natural sources can bring about groundwater contamination with nitrate. Nitrate-defiled water can bring about blue infant disorder if expended. Together with abundance P, eutrophication can happen downstream as a result of overabundance supplement supply, prompting anoxic zones referred to as dead zone (Hangsleben and Suh. 2006).

2.2.2 Organic contaminants

Creatures and people use supplements from livestock excrements and bio solids as nourishment. Soil supplements are reused by returning such waste items to horticultural land. The excrements and bio solids in a few occurrences may contain poisons, including pharmaceuticals and personal care items (PPCPs).
There is a wide assortment and degree of PPCPs consumed by both people and animals, and each having an extraordinary science in earthly and water conditions and they have not been broadly evaluated for their consequences for soil, water,

and air quality. The levels of different PPCPs in sewage muck has been studied from wastewater treatment plants over the US by US EPA (USEPA Report 2013).

2.2.3 Heavy metals

The horticultural practices, for example, water system, utilization of composts, natural wastes, animal excrements, and material processing side effect wastes are the significant contributions of heavy metals (e.g. lead, cadmium, arsenic, mercury) into horticultural frameworks (Ganje and Selenium. 1966).

2.2.4 Tillage and nitrous oxide emissions

Normal soil biogeochemical forms result in the discharge of different greenhouse gasses, including nitrous oxide. Agrarian administration practices can influence emanation levels. For instance, cultivation levels have likewise been appeared to influence nitrous oxide outflows. (Mackenzie, af et al. 1998).

2.2.5 Soil erosion and sedimentation

Wasteful land cover and serious administration in agribusiness contributes extraordinarily to soil disintegration and deposits. The sedimentation in spillover water influences the nature of the water in a few ways. Sediments amassing can lessen the transport limit of trench, streams, waterways, and route channels. It additionally confines the degree of light entering the water, influencing the aqua biota. The ensuing turbidity from sedimentation can influence the sustaining propensities for fish, influencing their populace dynamics. Sedimentation likewise influences the transport and amassing of poisons, including phosphorus and different pesticides. (Hangsleben, and Suh. 2006).

2.3 Effects of industrialization on water quality

Enterprises are the principle ecological contaminations; either straightforwardly or by implication (Glyn and Gary, 1996). Effluents from ventures are polluted with chemicals that are lethal to human and oceanic life, and were found to change the physical, chemical and natural condition of receiving water bodies (Kupechella and Hyland, 1989).

Nonstop contribution of toxins into sea-going biological communities from enterprises has had long haul consequences for environment working; adjustments in nourishment accessibility and an extraordinary hazard to the automatic ability of the biosphere has happened. These industrial wastes incorporate overwhelming metals dioxins, polyaromatic hydrocarbons (PAHS), petrochemicals, pesticides, polychlorinated biphenyls (PCBb), phenolic mixes and microorganisms (Fakayode, 2005).

The sort of release from enterprises are assorted and industry related. The uncivilized dumping of enterprise waste may contribute fundamentally to water contamination as is Nairobi (Phiriet al., 2005). Such water contamination upsets the equilibrium of the environment inside, bringing about the loss of different creature and plant species in the water. Contamination likewise lessens the capability of water as an asset for the different uses by making it inadmissible for different uses and furthermore troublesome and expensive to treat to required quality for consumption.

2.4 Water Quality Parameters

It is a complex aspect to evaluate. The condition of the aquatic ecosystem is determined by many things. Parameters are related and related, including acidity, alkalinity, ammonia, carbon dioxide, chlorine, nitrate, dissolved oxygen, phosphate, temperature and turbidity.

2.4.1 Acidity

It is the quantifiable capacity to react with a strong base to a designated pH. Acidity is the quantity of an aggregate property of water and can be construed in terms of specific substances only when the chemical composition of the sample is known (Standard Methods, 1995).

2.4.2 Alkalinity

Also referred to as the buffering capacity of a compound. It refers to the capacity for a compound to neutralize acidic solution and resist changes in pH. Alkalinity denotes the amount of alkaline compounds in the solution; the carbonates, bi-carbonates and hydroxides. (Stream keeper's Field Guide, 1991).

2.4.3 Conductivity

It is the measure ability of water to pass an electrical current. It indirectly measures the presence of inorganic compounds in solution such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron and aluminum.

The presence of these compounds in solution increases the conductivity of water. Organic substances e.g. oil, alcohol, and sugar are poor conductors of electricity. Inorganic dissolved solids are vital ingredients for aquatic life.

They modulate the movement of water in and out of organisms' cells and are building blocks of the molecules essential for life. A high concentration of dissolved solids, can result into a water balance problems for aquatic organisms and decrease dissolved oxygen levels (Stream keeper's Field Guide, 1991).

2.4.4 Dissolved Oxygen

The amount of Dissolved Oxygen (DO) in water is expressed as a concentration. A concentration is the amount of weight of a particular substance per a given volume of liquid. Streeter-Phelps equation determines the relation between the dissolved oxygen and the biological oxygen demand over time and it is a solution to the linear first order differential equation.

The DO concentration in a stream is determined in milligrams per liter of water or solution or can also be expressed as parts per million (ppm) (Stream keeper's Field Guide, 1991).

2.4.5 Hardness

Hardness is usually applied in assessment of the quality of water supplies. It is governed by the content of calcium and magnesium salts mainly combined with bicarbonate and carbonate to constitute the temporary hardness and with sulfates, chlorides, and other anions of mineral acids to constitute permanent hardness (Wetzel, 1983).

2.4.6 Metals

The effects of metals in water and wastewater vary from beneficial through troublesome to dangerously toxic.

Particular metals are essential and beneficial depending on their concentration while others could have adverse effects to consumers, wastewater treatment plants, and receiving water (Standard Methods, 1995).

The main mechanism for toxicity to organisms that exist in water bodies is by absorption or uptake across the gills. In this biological process, metal is in solution form. This does not imply that particulate metal is non-toxic but it exhibits less toxicity than does dissolved metal (U.S. EPA, 1996).

Not all metals are highly poisonous in trivial amounts as are the "heavy metals" which include copper (Cu), iron (Fe), cadmium (Cd), zinc (Zn), mercury (Hg), and lead (Pb) and are documented to be the most toxic to aquatic organisms. Particular water quality characteristics which affect metal toxicity include temperature, pH, hardness, alkalinity, suspended solids, redox potential and dissolved organic carbon. Metals toxicity can be reduced when it binds itself organic and inorganic compounds (Duffus, 2002)

2.4.7 PH

pH is a significant limiting chemical factor for aquatic life and it is expressed in a scale which ranges from 1 to 14. The aquatic organism's biochemical reactions maybe disrupted in a stream that is either too acidic or basic by interfering with the $H+$ or $OH-$ ion activity. A solution with a pH less than 7 has more $H+$ and is acidic while a solution with a pH value greater than 7 has more $OH-$ activity and is basic or alkaline.

The pH scale is logarithmic i.e. as you go up and down the scale, the values change in factors of ten. A one-point pH change indicates a tenfold increased or decreased the strength of the acid or base.

Water streams usually have pH values ranging between 6 and 9, depending on the dissolved substances that originate from bedrock, soils and or further materials in the watershed.

pH fluctuation changes the aspects of water chemistry e.g. as pH increases, lesser amounts of ammonia are required to attain a level that is toxic to the fish, as pH decreases, there is an increase in metal concentration due to increased ability of metals to be dissolved from sediments into the water stream (Stream keeper's Field Guide, 1991).

2.4.8 Suspended Solids

It is a measure of the suspended and dissolved solids in a body of water and it relates to both conductivity and turbidity. To determine the total suspended and dissolved solids, a sample of water is placed in a drying oven to evaporate the water, leaving the solids. To measure dissolved solids, the sample is filtered before it is dried and weighed. To calculate the suspended solids, the weight of the dissolved solids is subtracted from the total solids. (Stream keeper's Field Guide, 1991)

2.4.9 Temperature

Water temperature regulates several factors in aquatic life: rate of metabolic activities, reproductive activities and life cycles. Wide fluctuations of temperatures may result in undesired or malfunctioning of metabolic activities. Concentration of dissolved oxygen in a water body is a direct function of temperature; oxygen is easily dissolves in cold water.

There are several factors that can influence the stream temperature and can vary seasonally, daily, and even hourly, particularly in smaller sized streams. Spring discharges and overhanging canopy of vegetation provides shade which helps buffer the temperature fluctuation. Water temperature is also influenced by the quantity and velocity of stream flow; the sun has much less effect in warming the waters of streams with greater and swifter flows (Stream keeper's Field Guide, 1991).

2.4.10 Turbidity

Turbidity refers to the degree of the cloudiness of water which could be caused by suspended solids and plankton. Moderately low levels of turbidity indicate a healthy, well-functioning ecosystem, with moderate amounts of plankton present to fuel the food chain. Conversely, high levels of turbidity pose several problems for stream systems including blocking out the light required by submerged aquatic vegetation. It can also raise surface water temperatures to above normal because suspended particles near the surface facilitate the absorption of heat from sunlight.

Suspended soil particles may convey nutrients, pesticides, and other pollutants through a stream system, and they can bury eggs and benthic critters when they settle. Turbid waters may also be low in dissolved oxygen. High turbidity may result from sediment bearing runoff, or nutrients inputs that cause plankton blooms. (Stream keeper's Field Guide, 1991)

2.5 Overview of Nairobi City

2-1: General Information on Nairobi

PARAMETER	**STATISTIC**
Inhabitants	3,523,000 (2010)
Population density	5,061 persons/km^2
Population growth	2.8 % between 2005-2015 (UN-HABITAT, 2010)
GDP (estimated in 2008)	US$12 billion (Hawksworth et al.,2009)
Contribution to national GDP	60 % (Mafuta et al., 2011)
Area	696 km^2 (UN-HABITAT, 2010)
Climate	Subtropical highland climate
Altitude	1,650 m
Water Demand.	700m^3/Day (in 2003) (Dudley & Stolton, 2003)
% households with water access	50 %
water loss due to leakage in pipe systems and illegal connections	Up to 50 % (Dudley & Stolton, 2003)
Water price for domestic households	minimum 200 KSH (US$ 2.1027) per month when no meter is installed
% households with sewerage services	48 % (GoK 2010a)
% wastewater treated	up to 80 %
Main water sources	Rivers from the Aberdare Range Nairobi aquifer
Main water problems	Leakage due to over-aged infrastructure Lack of access to water supply in informal settlements Local authority lacks capacity

(Source: Athi Water Services Board-Annual Report 2010)

2.5.1 General information

Nairobi has encountered fast development after some time, from a little railroad station in 1899 to one of Africa's 15 biggest urban communities. Presently it is the most heavily possessed city in the East Africa with a populace of more than 3.5 million individuals. The high rate of casual and impromptu settlements, alongside a yearly populace development of 2.8 % by and large, is a test to the specialist's ability to manage water shortage in a successful and economical way.

2.5.2 Catchment Area

The water supply to Nairobi is prevalently from streams with sources in the Aberdare Range and the Mt. Kenya water catchment territory, the Aberdare Range, stretches out more than 160 km, north of Nairobi. Firm regulation of the mountain rainforest biological system is of most significance for the city's water supply security. Quality water for the metropolitan range must be ensured by a sound biological system, in this way diminishing the expenses for water treatment and the risk postured to human wellbeing. In spite of the fact that the Aberdare National Park (76,619 ha) is a safeguarded territory (IUCN Category II), the general catchment region has encountered tree lumbering before (Dudley and Stolton, 2003). Latest reviews however demonstrate a decrease of ecological degradation alongside a 111 % expansion of secured indigenous woodland cover (62,000 ha in 2000 to 131,000 ha in 2010) (Mungai et al., 2011; Mafuta et al., 2011).

2.5.3 Access to water

Information from Athi Water Services Board (AWSB) measures unaccounted for water having decreased from 65% to 42 % since its commencement.

Unlawful water use and underground spillage from the insubstantial water channeling framework represent lost water (Mufata et al., 2011).

Current estimates are that a portion of Nairobi's occupants have access to channeled water and about 40% are recipients of water at least once a day. The casual settlements which have an expected 60% of the occupants are most subjected to water shortages: (NCWSC and AWSB, 2009). The more than 200 informal settlements in Nairobi are in need of satisfactory access to quality water and sanitation, and 44 % of Nairobi's inhabitants live underneath the neediness line (SID, 2004). Deficient channeled water connection frequently prompts high water costs at water stands. NCWSC and AWSB reports around 22 % of occupants of informal settlements have a household connection, while an expected 75 % secure their water predominantly from water booths, worked by group gatherings, singular business entrepreneurs, or push-truck sellers.

Water is distributed at about KSH 100 to 250 for every m^3 (US$ 1.1 to 2.6), a value that is over that of NCWSC's normal water cost of KSH 45/m^3 (US$ 0.5) and embraced cost for water in casual settlements of KSH 10-15/m^3 (US$ 0.1 – 0.16). Margins are included by the affiliates and the rate is inaccurately charged. That makes the casual settlement inhabitants to be customers paying premium rates in the city per cubic meter, and altogether, commit a more noteworthy share of their month to month wage on water. Basing on the assessments of normal month to month pay in Nairobi's casual settlements a cubic meter of water from a booth represents 3-8 % of the month to month compensation rather than 0.5 % while paying the official water charge (NCWSC and AWSB, 2009).

Satisfactory water supply to occupants of Nairobi is an illusion for some, particularly those in informal settlements where 12% of the plots have water accessible, while around 86% of the populace gets its supply from water stands.

Let down of the NCG in dealing with the developing water demand has committed most engineers to take advantage of the effectively drained ground and surface water assets. Harvesting water from waterways and the sinking of shallow wells and boreholes is expanding. Most boreholes are being bored unlawfully and reached out to tap further levels, representing a quiet risk to Nairobi's aquifers.

2.5.4 Water Quality status for Nairobi

The Nairobi aquifer groundwater quality is by and large great meeting the drinking water standards, with the exception of fluoride (Foster and Tuinhof, 2005). The water got from Kikuyu Springs is just treated by chlorination while whatever remains of the surface water, which by and by records for most of Nairobi's water, is intensely dirtied and along these lines has high treatment costs. Poisons are principally agro-chemicals, heavy metals, microbial, and natural contaminations (UNEP, 2007). Debasement of upstream environments brings about poor water quality and increasing expenses for water treatment. (Msafiri, 2008).

2.6 Overview of Water Resources in Nairobi

2.6.1 Rainfall/ Precipitation in Nairobi, Kenya

Nairobi gets up a normal of 925 mm (36.4 in) of precipitation every year, 77.1 mm (3 in) every month. By and large there are 89 days for every year with more than 0.1 mm (0.004 in) of (precipitation) or 7.4 days with an amount of rain, hail and so forth every month. The driest climate is in July when a normal of 19 mm (0.7 in) of (precipitation) happens. The wettest climate is in April when a normal of 206 mm (8.1 in) of (precipitation) happens

2.6.2 Surface Water

The Nairobi water utility depends solely on surface water to meet the expanding city's water needs. In 2010 surface water supply for Nairobi was 484,500 m3/day. Supplies more often than not have satisfactory capacity to meet the city amid an ordinary dry season, yet with expanded dry spells the water supply can be lower than normal. (ADB Report 1998)

The Nairobi water utility gets 94% of its water from the Tana River basin north of the city through three supplies: the Sasumua Dam on the Chania River, the Thika Dam which is the biggest, providing 225,000 m^3/day and the Chania-B Dam. There are two treatment plants for the repositories, the biggest one being in Ngethu. The balance of 6% of the water originates from neighborhood sources: the Kikuyu Springs and the Ruiru Dam, both situated in the Athi River Basin and whose water is dealt with in two slighter treatment plants (AWSB 2011).

2.6.3 Ground water

Groundwater supplies an extra 85.000 m3 for every day or more from an expected 3000 boreholes, up from an expected 2250 boreholes in 2001. The groundwater table has declined; in one well it declined by 40 meters in the vicinity of 1958 and 1996. The normal profundity of new wells in 2001 was 238 meters. In that year 97 new wells were bored due to a dry spell. Most wells are worked by industries, inns, ranches for blossom creation in nurseries, and private houses in parts of the city that get just sporadic supply (e.g. Langata and Karen). Groundwater is additionally used to flood plants and to supply tankers that exchange the water. Numerous private well proprietors are likewise associated with the mains water supply system and utilize groundwater as a move down supply. Common groundwater quality is great.

There is few information on whether the aquifer has been contaminated or not. (Stephen cultivate and Albert tuinhof 2005). At the stature of another dry spell in 2008/2009, Athi Water Services Board sunk more than 40 crisis boreholes in different parts of the city and associated them to the conveyance network. (Jambo 2011).

2.7 Overview of past Studies

2.7.1 Quality of Nairobi runoff

As indicated by research completed by Otieno (1992) nature of Rain and Storm Water is great in Nairobi and can fill in as a reasonable wellspring of water with regard to physical, Chemical and bacteriological criteria. Polluting of water for the most part happens amid accumulation and managing. In the event that these viewpoints are painstakingly managed, and flushing frameworks introduced to guarantee the dirtied introductory flush is not gathered by the compartments, the nature of water gathered in Nairobi is appropriate for human needs. On the off chance that fundamental, basic treatment techniques, e.g. sanitization could be utilized to make the water generally satisfactory for human utilization. (Otieno, 1992).

2.7.2 Studies on surface water quality in Nairobi

Musyoki et al (2013) did evaluation of the bacteriological nature of the waterway of metropolitan capital city of Kenya in East Africa; Nairobi Five testing focuses were mapped in the Nairobi and Athi streams. Tests were gathered from recognized focuses along Nairobi and Athi River and taken to the research facilities for investigation. The review uncovered that the microbiological pollution of Nairobi and Athi waterways was inadmissibly high according to Kenya benchmarks, and WHO rules for drinking water and agrarian utilize.
The water is not consumable, and it represents a wellbeing danger to groups that depend on the two waterways as an essential hotspot for local utilize.

2.7.3 Surface water quality in Kenya's urban environment: a case study of Githurai

Kaluli et al (2009) did a water quality evaluation of stream Kiu in Githurai region of Nairobi City. The review involved inspecting of water from distinguished focuses along the waterway, doing a study and furthermore getting water information from the district of Ruiru. The review uncovered that the surface water in Githurai is exceedingly dirtied that has prompted expanded instances of water borne ailments of the occupants as showed through expanded successive visits to healing centers than already experienced.

2.7.4 Temporal changes of sediment dynamics within the Nairobi River sub-basins between 1998–2006 time scale, Kenya

Kithiia (2008) research completed in the years 1998-2005 inside the Nairobi River bowls on the impacts and ramifications of silt loads on water quality. The Study involved gathering tests from chose locales as for saw arrive utilize impacts inside the streams researched as identified in the field. The predominant land-utilize movement was utilized as the primary contributing variable in finding the inspecting point. The examples were later taken to labs and broke down. The review discovered that land utilize changed from dominatingly agrarian in the upper achieves (headwater regions) to overwhelmingly urban in the center ranges of the bowl and tempest water can successfully tidy up the waterways amid the blustery season, since water can traditionally effortlessly be dealt with if physically dirtied. In view of this it was prescribed that the declining water quality in the Nairobi River bowls requires substantially more consideration from policymakers than is as of now the case.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Sites

3.1.1 Sampling locations

Two locales expressive of various land utilization and ecological settings of the City of Nairobi were recognized for sample collection and investigation of precipitation and overflow as per the reason for the review. One of the points was at Jomo Kenyatta International Airport which spoke to a modern setting while the other site was at the College of Agriculture and Veterinary Sciences (Upper Kabete Campus), University of Nairobi, Kenya, which spoke to a sub-urban zone halfway possessed with urban agrarian exercises and thickly scope with trees. Figure 1 area of testing destinations

3.2. Sampling of Rainwater and Storm runoff

A water jug was set no less than two meters over the ground in an open field to gather rain water. The jug was set over the ground to stay away from odds of sullying from water sprinkling from ground.

Accumulation of tempest water included gathering of water from tempest depletes inside the areas of the examination zone from tempest depletes beforehand distinguished. The tempest water overflow was gathered towards the finish of the precipitation.

The containers were named with

- Name of site;
- Date of sampling;

- The sample site number,
- Station name ,
- The coordinates of the sample site

Four samples were then carried in watertight bottles and to the Laboratories.

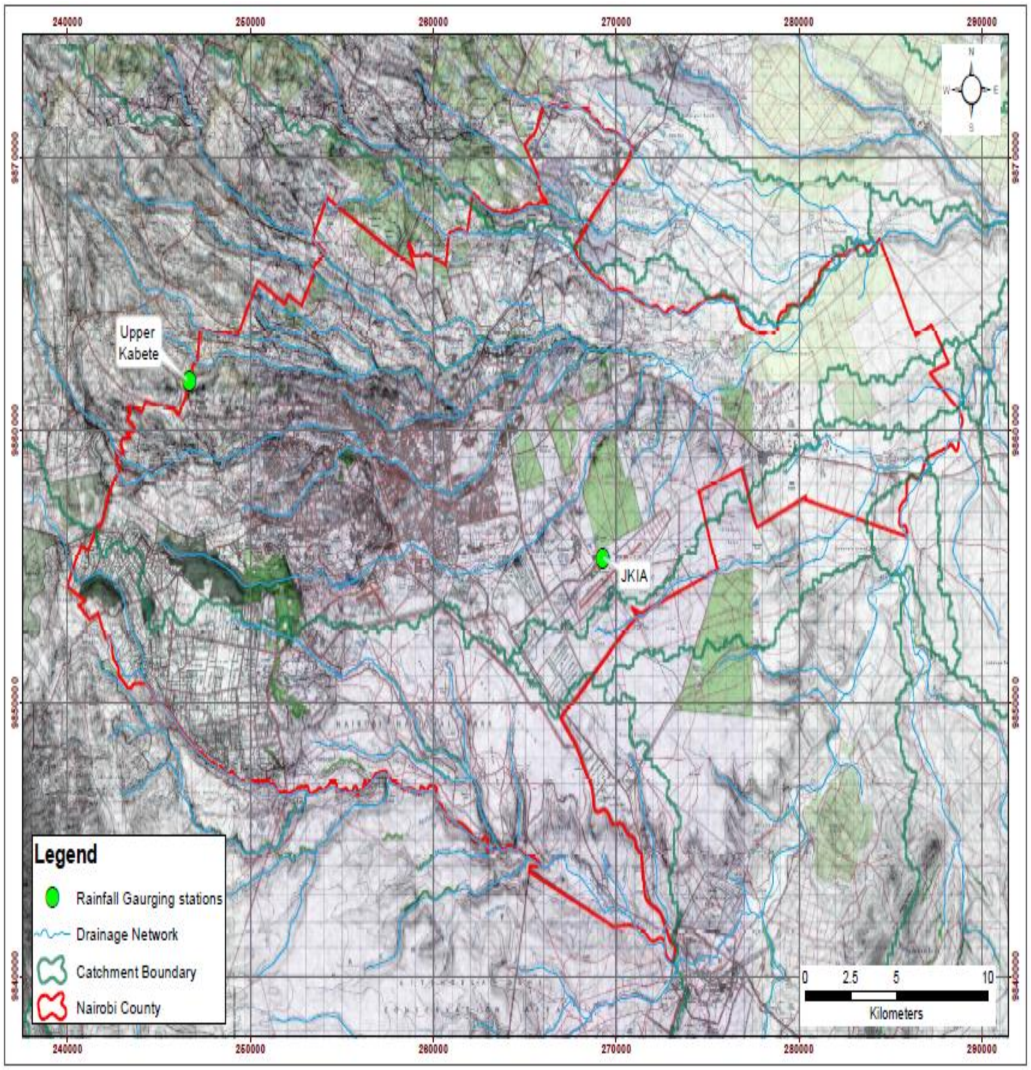


Figure 2- 1: Location of Sampling Sites

3.3 Laboratory analysis

The gathered specimens were taken for research facility examination to the general wellbeing lab, Department of Civil and Construction Engineering, University of Nairobi Physical and concoction investigation was completed in the labs to decide the water quality parameters.

The convergence of every parameter was resolved in each example. The water tests were broke down for physicochemical qualities. A Total of 15 physicochemical parameters were dissected in particular pH, Apparent Color (AC), True Color (TC), Conductivity, Turbidity (TU), Calcium hardness, Total Alkalinity, Dissolved Oxygen, Chloride, Total Suspended Solids, Total Dissolved Solids, Total Hardness, Nitrate and Nitrite including some heavy metals to be specific Iron and Manganese.

Tests were investigated by Standard Methods for Examination of Water and Waste water (APHA, 1998) and the Association of Official Analytical Chemists (AOAC).

3.3.1 pH

pH was measured utilizing a pH meter (Mettler Toledo 320 model) as indicated by APHA (1998).

3.3.2 Electrical conductivity (EC)

EC was measured in-situ both in the gushing divert and in the stream utilizing a Mettler Toledo MC 226 conductivity meter. The EC meter was exchanged on and its test plunged into the example contained in a container. The electrical conductivity was perused specifically and recorded in µScm-1.

3.3.3 Turbidity

Turbidity levels were measured in Nephelometric units (NTUs) utilizing the HACH 2100A turbidity meter.

3.3.4 Color (Apparent Color)

Color was resolved utilizing a Spectrophotometer (DR 20800 model) as indicated by APHA (1998).

3.3.5 Total Nitrogen (TN)

25 ml of the example was blended with 45 ml of concentrated ammonium chloride arrangement, 25 ml were gathered and 1.0 ml of shading reagent was added to it. The TN concentration was checked specifically utilizing DR4000 spectrophotometer at 543 nm.

3.3.6 Total Phosphorus

Total Phosphorus was resolved calorimetrically technique utilizing noticeable spectrophotometer (display DR 3800-HACH) as indicated by APHA (1998).

3.3.7 Chloride

This anion was controlled by titration of the example with silver nitrate. To 100ml example was included potassium chromate (5%, 1ml) and titrated with 0.1 M silver nitrate answer for the principal appearance of a buff shading (AOAC, 2002).

3.3.8 Sodium

Sodium was resolved utilizing a fire photometer (Model CORNING M410) as indicated by APHA, 1998.

3.3.9 Heavy metals and Calcium

Calcium, lead, copper and cadmium were resolved utilizing Atomic Absorption Spectrometer (display AA6800-SHIMADZU) as per APHA, 1998

3.4 Data analysis

Analysis of data was done using MS Excel and statistical analysis using ANOVA.

The hypothesis of analysis was to determine whether there was a difference in parameters between the rainfall and storm water in Kabete and JKIA.

The two hypotheses were:

i. The two stations analysis are equal; $H_o = u_1 = u_2$

ii. The two stations analysis are not equal; $H_1 = u_1 \neq u_2$

Analysis of variance (ANOVA) analysis was considered here since there were many variables within a single station at a time. Complete randomize block design (CRBD) of ANOVA was used here and the data used was the mean of the variables Detailed results of statistical Analysis is appended (Appendix A)

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

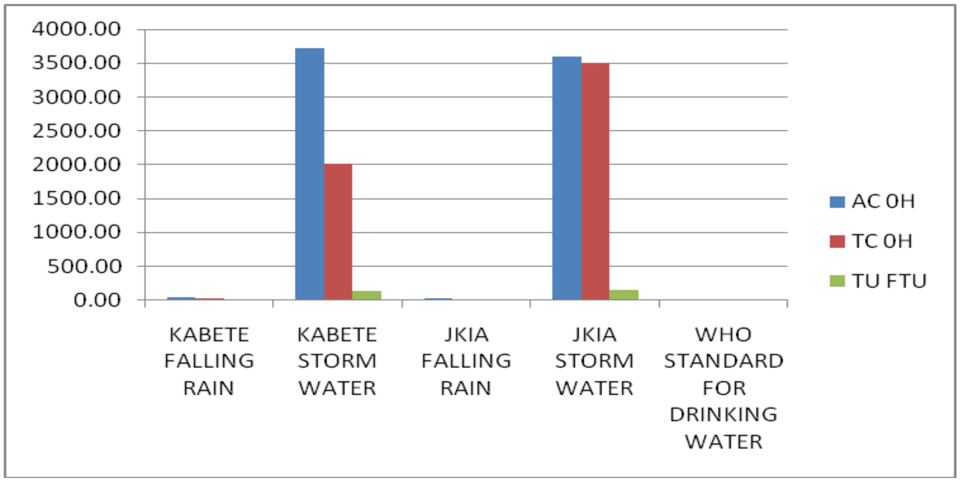
Results of the research investigation are annexed (Appendix B). Tables 4.1, 4.2, 4.3, demonstrate the consolidated after effects of Color, Physical properties and dissolved solids of the specimens gathered for falling precipitation and tempest water for Kabete and Jomo Kenyatta. The aftereffects of what were contrasted and standard rule delivered by WHO gauges and NEMA for water quality benchmarks in Kenya.

4.2 Color Attributes

Table 4-1: Water Color

	Color Attributes		
Site	Apparent Color (AC) ^{0}h	True Color (TC) ^{0}h	Turbidity (TU) Ftu
Kabete Falling Rain	41.7	36.7	2.3
Kabete Storm Water	3725	2016	145
Jkia Falling Rain	25	20	1.7
Jkia Storm Water	3600	3500	150
Who Standard For Drinking Water	Not Specified	Not Specified	

Figure 4- 1: Color Attributes for each site



Key: Apparent Color (AC), True Color (TC), Conductivity, Turbidity (TU)

4.2.1 Color (Apparent)

Apparent Color is of the entire water sample, and comprises of shading from both dissolved and suspended parts. The existence of color in water does not really show that the water is not consumable. Color generation substances, for example, tannins might be safe. Colors in common waters can originate from disintegration of natural matter and discharge of certain waste. Colors interfere with penetration of light and which influences photosynthesis. It might likewise hamper oxygen absorption from the environment.

The means of Apparent color (AC) for falling precipitation went from of 41.67 TCU at Kabete to 25 TCU at Jomo Kenyatta with a general mean of 33.33. The averages for AC went from 3725 TCU at Kabete to 3600 TCU at Jomo Kenyatta for tempest water with a general mean of 3662.2 TCU. (Table 4.1). In comparable situations there was no huge contrast (P =0.0.5, ANOVA) between the two sampling site.

The high values recorded at Kabete are most likely because of impacts of air pollution emerging from utilization of chemicals to boost agrarian generation and discharges from Zero grazing units (Wigley and Jones 1985). As far as its use, color impacts the taste and acceptability for utilization thus far WHO and NEMA have not yet developed guidelines. Moderately lower values recorded at JKIA when contrasted with Kabete is mostly credited to low level of contamination subsequently of a well-kept and kept up condition at the air terminal.

4.2.2 True Color

True color is the color of the water after all suspended solids sediments are filtered. True color (TC) means ranged from 36.67 TCU at Kabete to 20 TCU at Jomo Kenyatta with a total average of 28.33 TCU for falling rainfall while means ranged from of 2016 TCU at Kabete to 3500 TCU at Jomo Kenyatta for storm water with an overall mean of 2758 TCU. (Table 4.1) In both scenarios there was no significant difference (P =0.0.5, ANOVA) between the two sampling sites. The highest value recorded at Jomo Kenyatta is probably due to the effects of water pollution from industrial wastewater mainly oils and fats.

4.2.3 Turbidity

Turbidity measures the clarity of the water or the ability of light to pass through the water. Turbidity is a measure of the amount of particulate matter and the dissolved color, which is suspended in water.

Turbidity in the range of 2.3 NTU at Kabete to 1.7 NTU at Jomo Kenyatta with a total average of 2FTU for falling rainfall the means ranged from of 145NTU at Kabete to 150 NTU at Jomo Kenyatta for storm water with an overall mean of 147.5 (Table 4.1) In both scenarios there was no significant differences (P =0.0.5, ANOVA) between the two sampling sites.

The highest value recorded at Jomo Kenyatta and Kabete to rain- is likely to rain through chemicals from fertilizers, pesticides and industrial sewage.

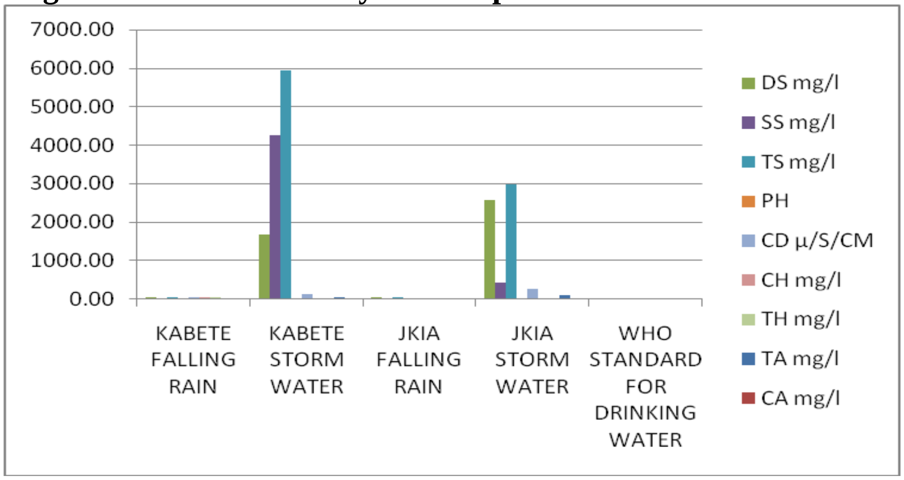
All values for the turbidity of the precipitation at the two sites and storm water exceeded the required limit values. The measurement of turbidity is an important test of water quality. By the standards of the World Health Organization, the water levels should be low as 0.1 NT. (WHO guidelines for drinking water, created in Geneva, 1993).

4.3 Physical Properties

Table 4-2: Physical Properties

	Physical Properties								
Site	Ds	Ss	Ts	Ph	CD	CH	TH	TA	CA
Kabete Falling Rain	53.33	0.	53.33	7.61	55.00	32.00	48	28	0.00
Kabete Storm Water	1690	4250	5940	7.55	110.50	0.00	0	42	0.00
Jkia Falling Rain	60	5	65	7.51	14.50	5.00	8	21	0.00
Jkia Storm Water	2590	400	2990	7.55	256.00	0.00	0.	98	0.00
Who Standard For Drinking Water	Not Specified	Not Specified	500	6.5 -8.5	5-50	150-400	300	20-200	O-75

Figure 4- 2: Trends in Physical Properties for each site



4.3.1 pH

PH is a measure of the level of activity of hydrogen ions in a solution, resulting in its acidic or basic quality. PH is measured on a logarithmic scale that typically ranges from 0 (acidic) to 14 (basic), with 7 being neutral.

The pH means ranged from 7.61 at Kabete to 7.51 at Jomo Kenyatta with an overall mean of 7.56 for falling rain while the means were similar at 7.55 at both sites for storm water with an overall mean of 7.55. (Table 4.2). In both scenarios there was no significant difference (P = 0.0.5, ANOVA) between the two sampling sites. The study revealed that the pH value of the both rain and storm water at both sites are slightly alkaline but within the permissible limits by NEMA (1999) standards.

The slight difference in pH levels is often due to the effluent from industrial wastes containing organic waste which is discharged into the storm water. (Chennakrishnan, 2008).

Agricultural activities contributed to elevated pH primarily in the form of nutrient runoff (most commonly fertilizer), as observed from Kabete.

4.3.2 Total dissolved solids

This refers to natural or added solutes present in water which includes the dissolved and suspended solids. Basically Solids are particles of sand, silt, clay, and organic material found in the water and are usually measured as a concentration, milligrams per liter (mg/L).

The Dissolved Solids (DS) means ranged from of 53.33mg/l at Kabete to 60mg/l at Jomo Kenyatta with an overall mean of 56.56mg/l for falling rainfall the means ranged from of 1690mg/l at Kabete to 2590mg/l at Jomo Kenyatta for storm water with an overall mean of 2140. (Table 4.2)In both scenarios there was no significant differences (P =0.0.5, ANOVA) between the two sampling sites.

The high values recorded at Jomo Kenyatta and Kabete for storm water are probably due to dust washed away from pavements that make their way into the storm water and human agricultural activities resulting in erosion of soil respectively. The values for Total suspended solids for falling rain in both sites are within the allowable limits whilst the values for storm water in both sides are extremely much higher than the allowable limits The tolerance limit for Total Dissolved Solids is 500 mg/l. High levels of suspended solids can cause problems for aquatic organisms, both as the solids travel through the water and after they are deposited (EPA. 2003).

4.3.3 Electrical Conductivity

Electrical Conductivity is a measure of how much total salt is present in the water. The more the ions, the higher the conductivity (Mosley et al., 2004).

The Electrical Conductivity (EC) means ranged from of 55 μS/m, at Kabete to 14.5 μS/m, at Jomo Kenyatta with an overall mean of 34.7 μS/m, for falling rainfall while the means ranged from 110.5 μS/m, at Kabete to 256 μS/m, at Jomo Kenyatta for storm water with an overall mean of 183.25 μS/m. (Table 4.2). In both scenarios there was no significant difference (P =0.0.5, ANOVA) between the two sampling sites.

High quality deionized water has a conductivity of about 5.5 μS/m, Allowable typical drinking water in the range of 5-50 mS/m. All the parameters are beyond the allowable range for drinking water except the value for falling rainfall in Jomo Kenyatta. The high values of EC in both sites for storm water could be attributed to release of effluents and agricultural fertilizers and blood containing nitrogenous compounds into runoff water which are nitrified to ammonium-nitrogen and nitrate resulting in high EC (Koushik and Saksena, 1999).

4.3.4 Total Hardness

Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking originally taken to be the capacity of water to destroy the lather of soap.

The Total Hardness (TH) means ranged from of 48mg/l, at Kabete to 8mg/l, at Jomo Kenyatta with an overall mean of 28mg/l for falling rainfall. (Table 4.2) There was no significant differences (P =0.0.5, ANOVA) between the two sampling sites for falling rainfall.

The values for hardness for rain water in Kabete was attributed to emission of calcium containing chemicals in the air from agricultural related activities for crop production and livestock production.

The maximum desirable limit for Total Hardness is 300 mg/l. (USEPA, 1986). Most of the values of the water samples were less than 60mg/l hence the water is classified as soft.

4.3.5 Total Alkalinity

The alkalinity of natural water is generally due to the presence of bicarbonates formed in reactions in the soils through which the water percolates. It is a measure of the capacity of the water to neutralize acids.

The Total Alkalinity (TA) means ranged from of 28mg/l at Kabete to 21mg/l at Jomo Kenyatta with an overall mean of 24.7mg/l for falling rainfall while the means ranged from of 42mg/l, at Kabete to 98mg/l at Jomo Kenyatta for storm water with an overall mean of 70mg/l. (Table 4.2).

In both scenarios there was no significant differences (P =0.0.5, ANOVA) between the two sampling sites.

The storm water the value at Jomo Kenyatta was higher which was attributed to $CaCO_3$, being leached from rocks and soil due to urban development effluent discharges from the industrial plants whilst for Kabete it is attributed to $CaCO_3$, being leached from soil due to cultivation of farms. All the values of the water samples were within the range of 20-200 mg/L hence the water is classified as typical fresh water.

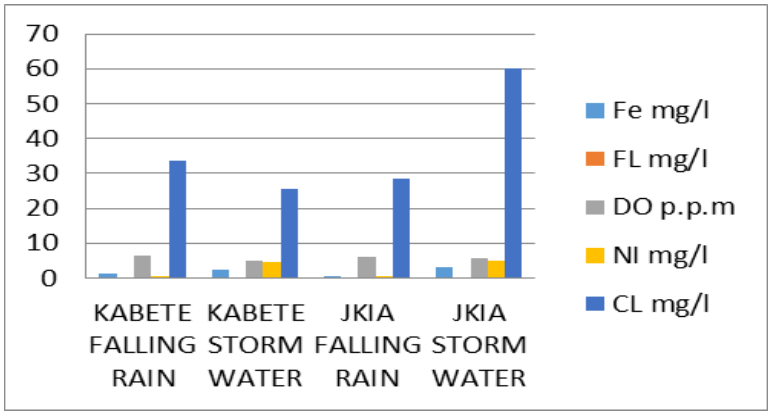
Alkalinity is significant in the treatment of wastewater and drinking water because it will influence treatment processes such as anaerobic digestion.

4.4 Dissolved Minerals

Figure 4- 3: Dissolved Minerals

	Dissolved Minerals				
Site	**Fe**	**Fl**	**Do**	**Ni**	**Cl**
Kabete Falling Rain	1.10	0.00	6.23	0.70	33.67
Kabete Storm Water	2.50	0.00	4.90	4.50	25.50
Jkia Falling Rain	0.10	0.00	5.90	0.40	28.50
Jkia Storm Water	3.00	0.00	5.60	5.00	60.00
Who Standard For Drinking Water	300	1.0	Not Specified	0.50	250

Figure 1.3 Trends in dissolved solids for each site



<u>4.4.1 Iron (Fe)</u>

Iron is a chemical element with symbol Fe and atomic number 26. It is by mass the most common element on Earth, forming much of Earth's outer and inner core. Iron is the second most abundant metal in the earth's crust, of which it accounts for about 5%.Elemental iron is rarely found in nature, as the iron ions Fe2+and Fe3+readily combine with oxygen- and sulfur-containing compounds to form oxides, hydroxides, carbonates, and sulfides.

The Iron (Fe) means ranged from of 1.1mg/l at Kabete to 0.1mg/l at Jomo Kenyatta with an overall mean of 0.6mg/l for falling rainfall while the means ranged from of 2.5mg/l at Kabete to 3mg/l at Jomo Kenyatta for storm water with an overall mean of 2.75mg/l. (Table 4.3). In both scenarios there was no significant difference (P =0.0.5, ANOVA) between the two sampling sites.

The high value recorded at Kabete and Jomo Kenyatta for storm water are probably due to geological formations; acid drainage; effluent discharges from agricultural activities and industrial plants. Most of the values of the water samples were beyond the permissible limit except for falling rain at Jomo Kenyatta.

4.4.2 Fluoride (FL)

Fluoride is an inorganic, monatomic anion of fluorine with the chemical formula F^-Fluoride is the simplest anion of fluorine. (Wells, J.C. 2008)

All the samples taken from both sites for falling rain and storm water registered no presence of fluorides which was attributed to occurrence of fluoride ions on earth in several minerals, particularly fluorite, but are only present in trace quantities in water. Fluoride is added to public drinking water to prevent tooth decay. Fluoride is added to toothpaste and mouthwashes so it can be applied directly to the teeth to prevent tooth decay.

4.4.3 Dissolved Oxygen (DO)

Dissolved oxygen measurements can be expressed as a concentration, milligrams per liter (mg/L), or as percent saturation (the amount of oxygen the water holds compared to what it could absorb at that temperature).

The Dissolved Oxygen (DO) means ranged from of 6.23mg/l at Kabete to 5.9mg/l at Jomo Kenyatta with an overall mean of 6.07mg/l for falling rainfall while the means ranged from of 4.9mg/l at Kabete to 5.6mg/l at Jomo Kenyatta for storm water with an overall mean of 5.25mg/l. (Table 4.3).In both scenarios there was no significant differences (P =0.0.5, ANOVA) between the two sampling sites.

The value at Kabete for falling rain was slightly higher for Jomo Kenyatta which was attributed to infusion of oxygen into the air a result of photosynthesis whilst the corresponding values for the storm water at both sites slightly lower due to contamination of storm water from fertilizers and industrial waste that affect the concentration of the dissolved oxygen. Currently NEMA and WHO have not yet developed guidelines for safe limits.

4.4.4 Nitrates (NI)

Nitrate is a polyatomic ion with the molecular formula NO_3^- and a molecular mass of 62.0049 g/mol. The Nitrates (NI) means ranged from of 0.7mg/l at Kabete to 0.4mg/l at Jomo Kenyatta with an overall mean of 0.55mg/l for falling rainfall while the means ranged from of 4.5mg/l at Kabete to 5mg/l at Jomo Kenyatta for storm water with an overall mean of 4.75mg/l. (Table 4.3). In both scenarios there was no significant differences (P =0.0.5, ANOVA) between the two sampling sites.

Permissible limit of nitrate is 45 mg/l. Most of the values of the water samples were beyond the permissible limit except for falling rain at Jomo Kenyatta. The storm water values at Kabete and Jomo Kenyatta were higher which was attributed to agricultural runoff of animal wastes and nitrogen-containing fertilizers concentrations of nitrate in the environment and effluent from sewage respectively. In both sites the values were within the safe limits as the WHO standard is 50mg/l.

4.4.5 Chlorides (CL)

The chloride ion is the anion (negatively charged ion) Cl^-. It is formed when the element chlorine (a halogen) gains an electron or when a compound such as hydrogen chloride is dissolved in water or other polar solvents (Wells, John C. 2008) Chloride exists in all natural waters, the concentrations varying very widely and reaching a maximum in sea water (up to 35,000 mg/l Cl). The Chlorides (CL) means ranged from of 33.67mg/l at Kabete to 28.5mg/l at Jomo Kenyatta with an overall mean of 31.37mg/l for falling rainfall while the means ranged from of 25.5mg/l at Kabete to 60mg/l at Jomo Kenyatta for storm water with an overall mean of 42.75mg/l. (Table 4.3).In both scenarios there was no significant differences (P =0.0.5, ANOVA) between the two sampling sites

The storm water the value at Jomo Kenyatta was higher which was attributed to pollution of a water by a sewage effluent since sewage is such a rich source of chloride, whilst for Kabete is due from soil and discharges from livestock enterprises. The safe limits by NEMA and WHO are 250mg/l signifying that is values area within the safe limits set for drinking water

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Comparing the values of water quality parameters for both sites, it was concluded that water quality of parameters for falling rain and storm water are not significantly different for the two sites. For storm water the water quality values registered some differences which were attributed to the existence of varied land use characteristics since runoff from different land uses load significant amounts of nutrients and contaminants into water.

From the results for falling rain at both sites, it was established that the quality of water is reasonably portable for drinking purpose with only limited treatment and proper handling at harvesting. Additionally the results for storm water is not suitable for portable uses but can be used for car washing, pavement cleaning and flower gardening and for recharging the groundwater for the city of Nairobi.

1.2 Recommendations

The following recommendations are made in furtherance of the study carried

- To establish any relationship between of intensity of rain received and the water quality parameters
- To establish if there is any relationship between the rainfall duration and the water quality parameters.
- Ascertain the changes in water quality throughout a given rainfall season
- Compare water quality changes for a long and short rainfall season for same calendar year

REFERENCES

ALLAN, J. D. (1995). ***Stream ecology. Structure and function of running waters***.

CHENNAKRISHNAN C, STEPHREN A, MANJU T AND RAVEEN R (2008): ***Water Quality status of three vulnerable freshwater Lakes of Suburban Chennai, India.***

CHUTTER, F.M (1998). ***Research on the Rapid Biological Assessment of Water Quality Impacts in streams and rivers***

ATHI WATER SERVICES BOARD (6 JUNE 2011). ***"Sasumua Dam Commissioned"***

DANIEL B. And A. KELLER, (1998). ***Environmental Science: Earth as a Living Planet.***

DEBORAH C., (1992). ***Water quality assessment: A guide to the use of biota, sediment and water in environmental monitoring,*** First edition 585p.

DUDLEY, N., STOLTON, S. (2003). ***Running Pure: The importance of forest protected areas to drinking water. World Bank/WWF***

DUFFUS J H, (2002). ***Heavy metals" a meaningless term? (IUPAC Technical Report)," Pure and Applied Chemistry*** Vol. 74, pp. 793-807.

EPA. (2003),"***National Management Measures to Control Nonpoint Source Pollution from Agriculture."***

FAKAYODE, S. O. (2005). ***Impact of industrial effluents on water quality of the receiving Alaro River in Ibadan, Nigeria. Ajeam-Ragee***, 10: 1-13

GANJE, T. J. SELENIUM. (1966), ***Diagnostic Criteria for Plants and Soils***: 394-404

GARG1 R. K., R. J. RAO and D. N. SAKSENA (2005***). Correlation of molluscan diversity with physico-chemical characteristics of water of Ramsagar reservoir, India***

GULLAN, P.J. and P.S CRANSTON, (2010). ***The Insects: An Outline of Entomology, 4th Edition. Blackwell Publishing*** UK: 584 pp.

HANGSLEBEN, M AND D SUH. (2006). Sediment pollution.

KOUSHIK, S. and D. SAKSENA, (1999): ***Physical-chemical limnology of certain fresh water bodies of central India***

JAMBO, N. (2011)"***Water supply to Nairobi".*** Retrieved 6 November 2011

KALULI J.W. C WANGECHI, and P HOME (2009). *Surface water quality in Kenya's urban environment*: Githurai Case Study

KUPECHELLA, C.E. and M.C. HYLAND, (1989). ***Environmental Science***

MAFUTA, C., R. K FORMO, C NELLEMANN, and F. LI, (EDS). (2011). ***Green Hills, Blue Cities: An Ecosystems Approach to Water Resources Management for African Cities***. A Rapid Response Assessment. United Nations Environment Programme, GRID-Arendal

MATHUTHU, A.S., MWANGA, K. AND SIMORO, A. (1997). ***Impact Assessment of Industrial and Sewage Effluents on Water Quality of the receiving Marimba River in Harare***.

MUMMA, A. M... LANE E., KAIRU, A TUINHOF. And R. HIRJI, (2011). ***Water Papers: Kenya Groundwater Governance Case Study***. Water Unit, Transport, Water and ICT Department

MITULLAH, WINNIE (2003) ***Understanding Slums: Case Studies for the Global Report on Human Settlements 2003***: The Case of Nairobi, Kenya...UN-HABITAT, Nairobi

MSAFIRI, P.W. (2008). ***Opportunities and Challenges of Implementing PES in the Water Sector***: A Kenya Buyer's Perspective. NCWSC, Nairobi

NCWSC & AWSB (2009). ***Strategic Guidelines for Improving Water and Sanitation Services in Nairobi's Informal Settlements***. Nairobi City Water and Sewerage Company and Athi Water Services Board, Nairobi.

OLIMA, WHA (1997) "***The Conflicts, Shortcomings and***

Implications of the Urban Land Management System in Kenya Habitat International Vol 21, No 3, pp. 319 – 331

PHIRI, O; P. MUMBA, B. H. Z. MOYO and W. KADEWA, (2005). ***Assessment of the impact of industrial effluents on water quality of receiving rivers in urban areas of Malawi***. Int. J. Environ Sci Tech 2(3): 237-244

SAGGERSON, .E.P. (1991)...***Geology of the Nairobi Area***.

ROBERTSON, A. AND W. DAVIS. (1993). ***The selection and use of water quality indicators***. p. 119-128.

STEPHEN, F and T. ALBERT (MARCH 2005). ***The Role of Groundwater in the Water-Supply of Greater Nairobi***. .Retrieved 6 November 2011

THE STREAMKEEPER'S FIELD GUIDE: *Watershed Inventory and Stream Monitoring Methods* **Revised Edition**

UN-HABITAT (2010). ***Solid waste management in the world's cities: water and sanitation in the world's cities 2010***. United Nations Human Settlements Programme. Earth scan, London

UON/UNEP. (2005)...***Water Quantity and Quality Assessment Desk Study***...Department. Of. Chemistry, University of Nairobi the Nairobi River Basin. Programme. Phase III UNEP, Nairobi

US EPA". WATER.EPA.GOV. (2013)-***bio solids: targeted national sewage sludge survey report - overview |***

USEPA (1986): ***Wetland Trends in Michigan since 1800***: A preliminary Assessment

WELLS, J.C. (2008). ***Longman pronunciation dictionary (3rd ed. Ed.).*** Harlow, England: Pearson Education Limited/Longman. p. 313

WETZEL, R. G. (1983). ***Limnology***. (2nd Edition)

WIGLEY T.M.L and P.D. JONES (1985*). "****Influences of precipitation changes and direct CO2 effects on stream flow***

APPENDIX A: STATISTICAL ANALYSIS

FALLING RAIN

		S_b	f_b	MS_b	Sw	fw	MS_w	F_{test}	Fcri@(1, 4) at 0.05		Result	Conclusion
	Apparent Colour (AC)	347.2222	1	347.2222	866.6667	4	216.6667	1.602564	7.71		$F_{test}<F_{cri}$	Accept Null Hypothesis hence no significant difference
	True Colour (TC)	347.2222	1	347.2222	866.6667	4	216.6667	1.602564	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
Colour	**Turbidity (TU)**	0.45	1	0.45	1.06	4	0.265	1.698113	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Dissolved Solids (DS)	55.55556	1	55.55556	1666.667	4	416.6667	0.133333	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Suspended Solids (SS)	31.25	1	31.25	50	4	12.5	2.5	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Total Solids(TS)	170.1389	1	170.1389	1316.667	4	329.1667	0.516878	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
	PH	0.011681	1	0.011681	0.420067	4	0.105017	0.111226	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Conductivity (CD)	2050.313	1	2050.313	1544.5	4	386.125	5.309971	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
Physical Properties	**Calcium Hardness (CH)**	911.25	1	911.25	1322	4	330.5	2.757186	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference

	Total hardness (CH)	2000	1	2000	1136	4	284	7.042254	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Total Alkanity (TA)	61.25	1	61.25	218	4	54.5	1.123853	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Iron (Fe)	1.25	1	1.25	5.48	4	1.37	0.912409	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Dissolved Oxygen (DO)	0.138889	1	0.138889	1.146667	4	0.286667	0.484496	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Nitrates(NI)	0.1125	1	0.1125	0.14	4	0.035	3.214286	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference
Dissolved solids	**Chlorides (CL)**	33.36806	1	33.36806	37.16667	4	9.291667	3.591181	7.71		F test<Fcri	Accept Null Hypothesis hence no significant difference

STATISTICAL ANALYSIS- STORM WATER

		S_b	**f_b**	**MS_b**	**Sw**	**fw**	**MS_w**	**F_{test}**	Fcri@(1, 2) at 0.05		**Result**	**Conclusion**
	Apparent Colour (AC)	11718.75	1	11718.75	13411250	2	6705625	0.001748	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
	True Colour (TC)	1651692	1	1651692	20122512	2	10061256	0.164164	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
Colour	**Turbidity (TU)**	18.75	1	18.75	22550	2	11275	0.001663	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
Physical	**Dissolved Solids**	607500	1	607500	6708300	2	3354150	0.181119	18.51		F	Accept Null Hypothesis

Properties	**(DS)**										test<Fcri	hence no significant difference
	Suspended Solids (SS)	11116875	1	11116875	1316500 0	2	6582500	1.688853	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Total Solids(TS)	6526875	1	6526875	2204730 0	2	11023650	0.592079	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
	PH	0	1	0	57.0027	2	28.50135	0	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Conductivity (CD)	15877.69	1	15877.69	66376.5	2	33188.25	0.478413	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Total Alkanity (TA)	2352	1	2352	9636	2	4818	0.488169	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
Dissolved solids	**Iron (Fe)**	0.1875	1	0.1875	9.5	2	4.75	0.039474	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Dissolved Oxygen (DO)	0.3675	1	0.3675	31.38	2	15.69	0.023423	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Nitrates(NI)	0.1875	1	0.1875	29.5	2	14.75	0.012712	18.51		F test<Fcri	Accept Null Hypothesis hence no significant difference
	Chlorides (CL)	892.6875	1	892.6875	3744.5	0	0	0	0		0	0

APPENDIX B: RESULTS OF ANALYSIS

FALLING RAIN KABETE

	COLOUR				PHYSICAL PROPERTIES								DISSOLVED MINERALS				
Date	**AC**	**TC**	**TU**	**DS**	**SS**	**TS**	**PH**	**CD**	**CH**	**TH**	**TA**	**CA**	**Fe**	**FL**	**DO**	**NI**	**CL**
	^{0}H	**^{0}H**	**FTU**	**mg/l**	**mg/l**	**mg/l**		**μ/S/CM**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**p.p.m**	**mg/l**	**mg/l**
11/24/2011	35	30	3.1	70	0	70	7.85	35	10	26	30	0	3	0	7	0.4	34
11/25/2011	25	20	1.8	30	0	30	7.76	45	26	46	18	0	0.3	0	5.5	0.8	31
11/28/2011	65	60	2	60	0	60	7.21	85	60	72	36	0	0	0	6.2	0.9	36
AVERAGE	41.67	36.67	2.30	53.33	0.00	53.33	7.61	55.00	32.00	48.00	28.00	0.00	1.10	0.00	6.23	0.70	33.67

STORMWATER KABETE

	COLOUR				**PHYSICAL PROPERTIES**								**DISSOLVED MINERALS**				
Date	**AC**	**TC**	**TU**	**DS**	**SS**	**TS**	**PH**	**CD**	**CH**	**TH**	**TA**	**CA**	**Fe**	**FL**	**DO**	**NI**	**CL**
	^{0}H	**^{0}H**	**FTU**	**mg/l**	**mg/l**	**mg/l**		**μ/S/CM**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**p.p.m**	**mg/l**	**mg/l**
24/11/11	3250	32	150	1680	1700	3380	7.56	90	0	0	46	0	2	0	5	3	17
25/11/11	4200	4000	140	1700	6800	8500	7.54	131	0	0	38	0	3	0	4.8	6	34
AVERAGE	3725.00	2016.00	145.00	1690.00	4250.00	5940.00	7.55	110.50	0.00	0.00	42.00	0.00	2.50	0.00	4.90	4.50	25.50

RAINFALL JOMO KENTATTA

	COLOUR				**PHYSICAL PROPERTIES**								**DISSOLVED MINERALS**				
Date	**AC**	**TC**	**TU**	**DS**	**SS**	**TS**	**PH**	**CD**	**CH**	**TH**	**TA**	**CA**	**Fe**	**FL**	**DO**	**NI**	**CL**
	^{0}H	**^{0}H**	**FTU**	**mg/l**	**mg/l**	**mg/l**		**μ/S/CM**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**p.p.m**	**mg/l**	**mg/l**
21/11/11	25	20	1.5	80	0	80	7.21	6	2	2	16	0	0.2	0	5.8	0.4	32
28/11/11	25	20	1.9	40	10	50	7.81	23	8	14	26	0	0	0	6	0.4	25
AVERAGE	25.00	20.00	1.70	60.00	5.00	65.00	7.51	14.50	5.00	8.00	21.00	0.00	0.10	0.00	5.90	0.40	28.50

STORMWATER JOMO KENYATTA

	COLOUR				PHYSICAL PROPERTIES								DISSOLVED MINERALS				
Date	**AC**	**TC**	**TU**	**DS**	**SS**	**TS**	**PH**	**CD**	**CH**	**TH**	**TA**	**CA**	**Fe**	**FL**	**DO**	**NI**	**CL**
	^{0}H	**^{0}H**	**FTU**	**mg/l**	**mg/l**	**mg/l**		**µ/S/CM**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**p.p.m**	**mg/l**	**mg/l**
28/11/11	3600	3500	150	2590	400	2990	7.55	256	0	0	98	0	3	0	5.6	5	60
AVERAGE	3600.00	3500.00	150.00	2590.00	400.00	2990.00	7.55	256.00	0.00	0.00	98.00	0.00	3.00	0.00	5.60	5.00	60.00

Colour: AC, TC, TU,
Physical properties: Conductivity, CA, CH, TH, TA, PH, SS, TS
Dissolved minerals: Fe, Cl, DS, NI, DO, FL
Biological properties: Not important since they require time to develop and we were collecting falling RW

TABLE OF AVERAGES

	COLOUR				PHYSICAL PROPERTIES								DISSOLVED MINERALS				
SITE	**AC**	**TC**	**TU**	**DS**	**SS**	**TS**	**PH**	**CD**	**CH**	**TH**	**TA**	**CA**	**Fe**	**FL**	**DO**	**NI**	**CL**
				mg/l	**mg/l**	**mg/l**		**µ/S/CM**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**p.p.m**	**mg/l**	**mg/l**
KABETE FALLING RAIN	41.667	36.667	2.3	53.333	0	53.333	7.606	55	32	48	28	0	1.1	0	6.233	0.7	33.667
KABETE STORM WATER	3725	2016	145	1690	4250	5940	7.55	110.5	0	0	42	0	2.5	0	4.9	4.5	25.5
JKIA FALLING RAIN	25	20	1.7	60	5	65	7.51	14.5	5	8	21	0	0.1	0	5.9	0.4	28.5
JKIA STORM WATER	3600	3500	150	2590	400	2990	7.55	256	0	0	98	0	3	0	5.6	5	60