FACTORS AFFECTING ACCESS OF WATER SUPPLY IN KISAUNI AREA, MOMBASA COUNTY, KENYA.

BY

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A Thesis Submitted in Partial Fulfillment for the Degree of Masters of Science in Hydrology in the Department of Geography & Environmental Studies, Faculty of Science of the University of Nairobi.

Declaration

This thesis is my original work and has not been submitted for examination to any other university.

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Dedication

This thesis is dedicated to my mother and children who are my source of encouragement and inspiration.

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Abstract

The present study, factors affecting accessibility of water supply options was conducted in Kisauni, Mombasa County with a main objective of finding the most accessible water supply in terms of quality, quantity and cost among the existing water supply options and also to access the role of solar powered desalination in improving accessibility of water supply in Kisauni. With water scarcity problem growing worse as the world population grows, water supplies need to be increased at household levels. Lack of clean drinking water to households has already had a significant effect on international development. In Mombasa 50% of the diseases reported are attributed to lack of access to clean water. Solving water crisis in its many aspects is one of the greatest challenges facing mankind, it is no wonder many are encouraged to look at the sea where the majority of world's water belong. Seawater desalination has been seen as a long-term freshwater source.

The study used questionnaires to get information on cost and quantity of water supply available to the residents. The questionnaires were randomly distributed to residents depending on their willingness to participate in the study. Water samples were collected from the various water sources using sterilized plastic water samplers to determine its quality through chemical and biological analysis. The study established that the available water supply options in Kisauni are not accessible in terms of quality, quantity and cost with tap water meeting WHO drinking water threshold but being highly costly and unavailable while Groundwater is readily available at a very affordable cost, but the quality is unfit for human consumption unless used with further treatment. Groundwater quality is both chemically and biologically way above the WHO specified threshold, with salinity and conductivity measuring up to 478.5 mg/l and 2180 µs/cm against the specified 250mg/l and 2000 µs/cm respectively. General Coliform counts and E.*coli* were 2100MPN/100ml and 1200MPN/100ml respectively against the specified nil. The study finds the use of small scale solar still to desalinate brackish groundwater as the most accessible. With a base area of 0.72m^2 producing an average of 1.97litres of desalinated water and 150m^2 expected to produce 410 litres per day other factors like weather conditions being held constant. The study recommends that more research and awareness should be conducted on solar desalination to help improve water supplies in the area.

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Operational Definitions

Desalination: refers to any several processes that remove excess salt and other minerals from water.

Saltwater: refers to water containing dissolved salts.

Solar Still: a structure for distilling water powered by the heat from the sun

Brackish water: water that has more dissolved salts than freshwater but less than seawater.

Potable water: this is water of sufficient quality to serve as drinking water.

Brine: this is water saturated or nearly saturated with salts

Seawater: water from the ocean or sea.

Accessibility: actual use of water by the population

Quantity: a particular or indefinite amount of water

Quality: a measure of excellence or state of being free from defects or impurities

List of Acronyms

MENA-	Middle East and North Africa
RES-	Renewable Energy Source
GoK-	Government of Kenya
KIHBS-	Kenya Integrated Household Budget Survey
KNBS-	Kenya National Bureau of Statistics
NWSS-	National Water Services Strategy
MWI-	Ministry of Water and Irrigation
TISDA-	Transparency and Integrity Service Delivery in Africa
AWSB-	Athi Water Services Board
MDG-	Millenium Development Goals
MWSSC-	Mombasa Water Supply and Sewerage Company
CWSB-	Coast Water Services Board.

CHAPTER ONE

INTRODUCTION

1.0 Introduction

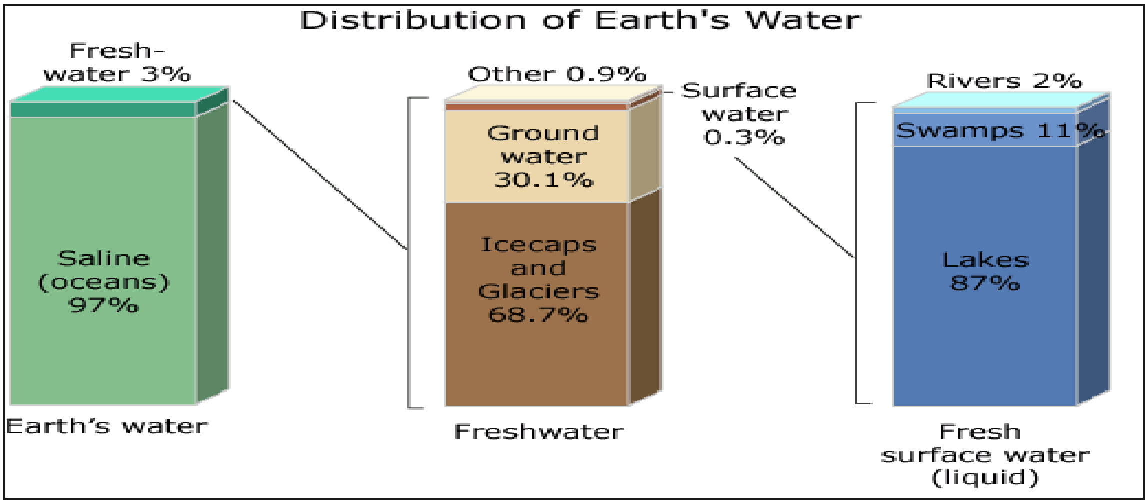
This chapter introduces the topic with background to the study, justification, objectives and hypotheses as well as the scope and study limitations.

1.1 Background to the Study

The world water crisis is one of the largest public health issues of our time. Nearly 1.1 billion people (roughly 20% of the world's population) lack access to safe drinking water (Water Aid, 2005).

David Seckler (2001) argues that water scarcity is now the single greatest threat to human health, environment and global food supply. This problem is not confined to a particular region of the world. A third of earth's population lives in water stressed countries and that number is expected to rise dramatically over the next two decades (UNICEF/WHO Water for life, 2005). The crisis is worse in developing countries, especially in Sub-Saharan Africa and South Asia.

Approximately 71% of the world is covered by water yet fresh water scarcity is one of the worst problems the world is faced with. This is due to the increasing demand for fresh drinking water caused by rapidly growing population, decreasing quality of the available waters due to water pollution and the increasing demand of expanding industries and agricultural activities (UNEP, GRID/ Arendal, 2002). However fresh water makes up only 3% of the water available on the planet and much of it is locked in glacier and icecaps as indicated in figure 1.1



Source: http//ga.water.usgs.gov/edu/waterdistribution.html accessed July 2012

Figure 1.1: World Water Distribution

It can easily be noticed from figure 1 that most of the world's waters are sea waters which cannot be used for many purposes while fresh water is unevenly distributed across regions as indicated in table 1.1

Region	**Available water (%)**	**Population (%)**
North and Central America	**15**	**8**
South America	**26**	**6**
Europe	**8**	**13**
Africa	**11**	**13**
Asia	**36**	**60**
Australia and Oceania	**5**	**<5**

Table 1.1: Water Distribution across Regions

Source: UNESCO/IHP (2001)

The global overview of water availability versus population as indicated in table 1 stresses the continental disparities, where in most cases the population outstretches the available water resources leading to water shortages.

In additional to natural water scarcity, chemical and physical contamination of water sources is a major global problem that has contributed to water scarcity. A large proportion of the world's population do not have access to good quality drinking water and around 80% of the world's diseases are attributable to inadequate drinking water supplies, sanitation and water treatment. As population of the world increases especially in developing countries it will become increasingly hard to keep up with the demand for proper sanitation and water treatment.

Africa though has 11% of the world's waters; it has a better water balance since it has 13% of the world's population (UNESCO/IHP, 2001). However, millions of Africans are faced with severe water shortages due to uneven water distribution, poor water infrastructure networks and lack of good political will.

In Kenya water crisis is disrupting both social and economic activities throughout the country. Unfortunately, the wave of water shortages is expected to continue. Like the rest of the world Kenyan water crisis is due to drought, poor management of the water supply, underinvestment, unfair allocation of water, rampant deforestation, pollution of water supply by untreated sewage and huge population. Kenya is limited by an annual renewable fresh water supply of only 647 cubic meters per capita and is now classified as a water scarce country (Kenya Water Report 2005). About 43% of the Kenya's population has access to clean and improved drinking water sources (World Bank 2010). The time intensive pursuit of water collection often prevents women from taking up income generating activities or in case of girls prevents them from going to school.

The Mombasa County has encountered persistent water problems due to many factors like rapid population growth and poor maintenance of existing water supply networks. Although the area is geologically rich in Groundwater which is often seen as an option, exploitation is limited due to salinity because of seawater intrusion (Musingi *et al* 1999). Ground water exploitation is also curtailed by pollution from numerous pit latrines and septic tanks in the town. Mombasa County therefore heavily depends on water sources from outside its jurisdiction for its potable needs. Its main sources of water supply are Mzima springs, Baricho water works and Marere supplying the Likoni area. Water from these reticulated supplies satisfies less than 50% of the demand hence it is of inadequate quantity.

There is growing realization that much of the world is already facing chronic freshwater shortages. This is because the principal manifestations of water crisis have already been observed. Such manifestations include inadequate access to safe drinking water for about 1.1 billion people, overexploitation of groundwater resources, overuse and pollution of water resources, and regional conflicts over scarce water resources sometimes resulting in warfare.

There are severe consequences for such drastic freshwater shortages because lack of access to clean water slows down the economy and strains development. This makes the economy suffer and increases global health problems, all these are looming dangers. Thus, provision of reliable supplies of water for drinking, washing and other needs is a cornerstone to global sustainable development.

1.2 Problem Statement

Although most of the world is covered with water worlds freshwater is incredibly rare, while there is enough water in the world it is unevenly distributed and often polluted, wasted and managed unsustainably.

The water scarcity problem is growing worse as the world's population grows and water supplies needs to be increased at household levels.

Lack of access to clean water has already had a significant effect to the lives of a third of world's population and if not addressed can have serious effect on international development.

Lack of access to clean water often forces people to obtain drinking water from unsafe sources. Poor water quality dramatically increases the risk of developing diseases such as typhoid, cholera, dysentery and other conditions.

People that live in water scarce areas often store the little water they have in their homes increasing the risk of contamination. Stored water also provides breeding ground for mosquitoes that carry malaria, dengue fever and other life threatening diseases, (World Nature Organization, 2009).

In Kenya, water shortage means that a large population of women and children spend up to a third of their day fetching water in the hot sun from the nearest fresh water source. This backbreaking work leaves half of the country's population vulnerable to serious dangers. In addition to exposure to the elements and risks of attack by predators, the primary water gatherers are also the most susceptible to water borne diseases.

Lack of access to clean water leads to use of contaminated water causes illnesses and death. Njeru (2010) discusses how water crisis in Kenya has had a tremendous impact to maternal care. Njeru gives an example of Kakamega district hospital which lacks sufficient supply of clean water. This situation worsens the patient's condition. Due to this water shortage this and other hospitals are forced to store water in buckets which is then provided to patients. This water is polluted with bacteria, viruses and parasites and many patients develop different diseases such as typhoid and cholera which is a serious threat to health of expectant mothers.

In Mombasa it has been revealed that more than 50% of all the diseases reported in the county are associated with lack of access to clean or good quality water and inadequate wastewater management (Munga 2002).

Lack of access to clean and safe water is an issue of major concern which requires immediate intervention.

1.3 Justification of the Study

Solving water crisis in its many aspects is one of its several challenges facing human kind as he confronts life in this millennium. Yet of all the social and natural resources crisis humanity face, water crisis lies at the center of his survival.

It's hardly surprising therefore that these looming shortages have encouraged many to look more seriously at where the overwhelming majority of water is "the sea" ,which is the source of the famous lament, "water, water everywhere nor any drop to drink"

Sea water desalination has been considered as a long-term freshwater source. It's fast emerging as a viable solution to drinking water all over the world and Mombasa County is no exception. It is expected to contribute in reduction of the supply-demand gap especially when other sources have been utilized as the case in the Mombasa County.

It has been argued that desalination might not be the magic bullet for fresh water shortage solutions because of the cost involved in removing salt from the water, new technological innovations continue to reduce the capital cost of desalination. It has now been discovered that desalination is among the most cost effective options for boosting drinking water supply.

It has been noted that Mombasa residents have been suffering for many years because of the non-availability of water that has not been taken seriously by the relevant authorities who have steadily allowed the water supply to deteriorate. The present study suggests that a permanent solution to water shortages in Mombasa is to invest in a desalination plant which is environmentally conducive and very possible since it has been done privately by some hotels.

Two reasons advanced for this suggestion are that Groundwater has become an unsustainable option due to pollution and insufficient replenishment as well as saltwater intrusion due to excess withdrawal and also global warming leading to sea level rise might find the coastal towns submerged in water so why not use this seawater.

In addition, setting up a county desalination plant is a capital intensive and to convince the policy makers to invest huge sums of money allocated for coast water development to build a desalination plant seems almost impossible.

The solution to persistent water problems in Mombasa County is therefore not to wait for water service providers' distribution facilities but for the residents to take care of their water needs at household level. Public supplies are desirable and deserve the highest priority but individuals can take actions to provide their own local domestic supply of good quality drinking water.

The present study examines the possibility of Mombasa residents adopting a concept that outlines an option for communities to consider developing better access to safe drinking water. The study envisages use of solar stills as cheap and affordable to desalinate seawater and brackish groundwater and to check if it can provide adequate clean good quality water for household supplies. Mombasa has an outstanding solar energy potential which is always maximum during the hot season when freshwater demand is high hence using solar energy to solve water scarcity is rather an obvious approach. Solar energy is clean, unlimited and very economic source of energy available to residents free of charge. Neither is sea water scarce in Mombasa due to its proximity to the Indian Ocean nor brackish water from boreholes and wells due to high water table levels hence salt water intrusion.

1.4 Objectives

The main objective of this study was to examine factors affecting accessibility of water supply in Kisauni, Mombasa County.

The specific objectives were:

1. To determine the effect of cost in accessing water
2. To establish the quality of water accessed by Kisauni residents.
3. To find out the quantity of water accessed by Kisauni residents.

4. To assess the role of solar powered desalination in improving accessibility of water supply to Kisauni residents.

1.5 Hypothesis(H_O)

The study hypothesizes that the accessibility of water supply is not dependent on its quality, cost and quantity. The following hypotheses were therefore formulated:

$Ho_{1.}$ There is no statistically significant relationship between quantity supplied by a water source and its viability as a water supply option in Kisauni Mombasa.

$Ho_{2.}$ There is no statistically significant relationship between the cost of water supplied by a water source and its viability as a water supply option in Kisauni Mombasa.

$Ho_{3.}$ There is no statistically significant relationship between quality of water supplied by a water source and its viability as a water supply option in Kisauni Mombasa.

1.6 Scope and Limitations

The study carried out research on which of the four water supplies options among piped, brackish groundwater, desalinated brackish groundwater/seawater was more accessible to Kisauni residents in Mombasa and by extension the Mombasa region in terms of quality, cost and quantity.

Desalination of brackish groundwater and seawater was done using solar energy through use of solar stills which were purely small scale. The supply of seawater was from the Indian Ocean while brackish water was from boreholes and wells. Piped water used from the taps supplied by Mzima springs from Taita-Taveta.

The study was restricted to Mombasa County due to its proximity to the Indian Ocean hence saltwater intrusion into the boreholes, as well as lack of rivers that can be used as an alternative freshwater supply.

The study was limited by lack of interest of households to respond to questionnaires and lack of knowledge and interest by respondents to matters that were crucial to this study.

The setups of solar stills were affected by changes of weather conditions. Unfavorable weather conditions served to prolong the time taken for experiment hence more time in the field in order to minimize the effects of bad weather.

Finances also proved to be a challenge to the study. The cost of buying materials for construction of solar stills and to pay human labor determined the number of solar still that were setup. Laboratory analysis also required money and that as well limited the number of samples that were analyzed. To solve this, the researcher used her own financial resources to supplement what was provided by the university.

CHAPTER TWO

LITERATURE REVIEW

2.1 Access to Water Supply and Factors Affecting it.

Access to safe water supply is measured by measured by the proportion of the population with access to an adequate amount of safe drinking water located within a convenient distance from the users dwelling according to WHO/UNICEF Joint Monitoring Program 2012. Access in this context is the actual use by the population.

The International Drinking Water Supply and Sanitation decade (1981-1990) envisaged as its primary goal the attainment of full access to water supply and sanitation by all inhabitants in the developing countries by the year 1990. Initiatives taken during the decade succeeded in providing access for additional 1 billion people to safe water supplies, (WHO/UNICEF 1990). This significant progress made during the 1980's is considered due to the discovery and improvement of simple and low cost water and sanitation technologies and the promotion of community participation. Yet, a large proportion of the world's population still live without access to safe water on which health and productive capacity depend on.

Africa has been faced by the challenge of rapid urbanization. Despite increasing access rate to improved water supply and sanitation in 1990's urban population growth out spaced the rate of expansion of improved services, (Dominguez 2012).

Dominguez 2012 concludes that service providers in SSA have been unable to keep up with urban population growth as they face distributional losses, low billing collection, overstaffing and under recovery of cost. Expansion of improved water supply is constrained by supply and demand factors. One side of supply insufficient production capacity and inefficiencies of service providers hamper reaching the universal access to improved water supply sources. On the demand side high connection fees in SSA and lack of land tenure prevents households from getting access to water supply (Banerjee and Morella 2011).

Existing tariff structures benefit the most rich as they are the ones who have the highest level of access to piped water and public taps (Banerjee and Morella 2011).

In Uganda water payments represent as much as 22% of the average income of households in the poorest 20% of the income distribution (UNDP 2006).

More urban dwellers turn to unimproved sources of water supply (wells and Boreholes) but dilapidation of access and lack of maintenance of these sources render many of them unsuitable to secure safe drinking water. For example in the Central African Republic only 10% of the wells and boreholes provide safe water (Dominguez and Foster 2011).

Kenya faces the challenges in realizing its 2030 vision for the water and sanitation sector "to ensure that improved water and sanitation are available to all".

The constitution of Kenya 2010 made access to water and sanitation the right of citizens. This is in line with the United Nations stipulation of access to water and sanitation as a human right that requires member states to deliberate targeted steps to ensure the progressive realization of this right (UNCHR 1990). Despite this ambitious objective the proportion of the people with access to an improved water supply remains low (Ministry of Water and Irrigation 2007).

The government of Kenya 2008 Poverty Reduction Strategy Paper (PRSP) recognizes the importance of safe clean water in reduction of poverty. The PRSP discusses the water situation, challenges to overcome the water crisis and a multiple approach to tackle the problem.

A case study conducted in Kangemi area by Transparency and Integrity Service Delivery in Africa (TISDA) 2011 revealed that many families in informal settlements suffer acute water shortages because some landlords have illegally continued to control access as well as cost of water without approval of service providers or the regulators. Such landlords determine when the tenants get water, how much they get and how much they pay for the water. They have made this certain by locking the yard taps which is the main source of water for these tenants. It also reveals that tenants in low income areas pay more for water than their counterparts in affluent areas. For example average consumption per household is 78.7 liters per day translating to 2.4m^3 per month which according to service providers it should cost Kshs 45 but with additional cost of Kshs 500- Kshs 1000 the landlord makes a profit of about Kshs 455.

Citizens' report card on urban water, sanitation and solid waste services (2007) argued volumetric cost very high. The difference in the amount paid is even more dramatic if the poor families have to supplement their water use from the kiosks or vendors. This could easily be the case if they required water during scarcity which they couldn't ride out as they did not have storage tanks. The heavy reliance by the poor on kiosks and vendors where water is more expensive in volumetric terms than private connection means that the poor pay large amounts of money per cubic meter than people with connection as is the case in the study area. that the unconnected households in most cases buy water from their connected neighbor hence the increased water use then drives the price into another tariff block making the

In 2009, an environmental impact assessment commissioned by the Athi Water Service Board (AWSB) stated that approximately 75% of city residents get water from pushcart vendors and resellers at water kiosks. These vendors' prices range between Kshs 5 and Ksh 10 per 20 liters jerrican which amounts to between Kshs 250/m^3 and Kshs 500/m^3. This makes the cost 26 times higher than regulation rate of Kshs 18.71/m^3 for domestic consumers published AWSB in their water tariff structure.

Similar to this is an article by Mugambi (2012) posted in business daily that Mombasa residents would pay higher water bills after the Mombasa Water Supply and Sanitation

Company (MWSSC) application for new tariff was approved by Coastal Water Services Board (CWSB). The tariff were adjusted such that those customers who consume between 0-6m^3 pay [a] flat rate of Kshs 400 up from Kshs 265 per month, those who use 6-20 m^3 pay Kshs 78 per cubic meter up from Kshs 44 per month, those who use 21-500 m^3 pay Kshs 90 per cubic meter up from Kshs 53 per month and those who consume up to 600m^3 pay Kshs 90 per cubic meter and those who use over 1200 m^3per cubic meter per month. The MWSSC justified the tariff adjustment arguing that last review was done in 2008, while residents complained that the increased tariff would push up the cost of doing business and the poor families will not access the essential commodity.

There are huge variations between rural and urban dwellers in terms of their access to safe water. While 68% of urban dwellers are dependent on unsafe water sources, 42.3% of their counterparts in rural areas are dependent on unsafe sources of water. Over 80% of people in West Pokot, Marakwet, Bomet and Mwingi districts depend on water sources considered unsafe, (KIHBS 2005/2006).

87% of people living in informal settlement in Mombasa use drinking water from an improved source and 49% are reportedly treating the water. More than 50% take less than 15 minutes to fetch drinking water (Multiple Indicator Cluster Survey, 2009). These figures show there is an urgent need to ensure easy access to clean water sources and awareness on how the community can ensure water is accessible through affordable rates, above all effective operations ensured to streamline the quality of water (Moraa, Otieno, and Salim 2012).

Socioeconomic aspects of water management along the Kenyan Coast were examined by Ochiewo, (2004) in a paper that discusses the challenges arising from freshwater shortages along the Coast of Kenya which includes Mombasa. He proposed policy options which may need to be implemented to minimize the water scarcity issues. He highlights that the coast experiences the problem of rapid population growth which leads to land use changes and because freshwater is scarce, water borne diseases are rampant and it has become a marketed good. The paper then suggests that due to critical freshwater shortages in the area water allocation decisions need to be given considerable attention. This highlights the real problem but proposing policy options which will require the government to implement is not an immediate solution to the residents of Mombasa because they need options that they can easily implement on their own.

As much as groundwater is one of water supplies in Mombasa for its potable needs in most of its parts, the information available on its quality suggests that aquifer contamination due to use of onsite sewage disposal and seawater intrusion is rampant, (Munga, 2004). He argues this in the report about pollution and vulnerability of water supply aquifers in Mombasa but gives no suggestion on a way of improving the quality of this great supply of water. Another study by Mwakio 1997 in Kwale district express similar concerns that the quality of groundwater developed in the area is too contaminated due to their interaction with pit latrine waste. He also examines groundwater system with respect to different lithologies. Unlike the previous study he recommends desalination should be a legislation placed on hotel owners who are practicing it.

Musing, Kiithia and Wambua (1999) examine urban growth of Mombasa Coastal town and its implications on surface and groundwater show that Mombasa receives its surface water supply from distant areas. Its main source being Mzima springs in Chyulu hills in Taita Taveta County while others include Baricho, Marere and Tiwi boreholes in the south coast. Their work highlights how wanting the water situation is in Mombasa and the importance of local solution to this problem.

2.2 Desalination as an option

Desalination is the process whereby potable water is recovered from salt water (seawater or brackish water). The desalination process has been known since the ancient times but perhaps the earliest known seawater desalination process took place in AD 200 where the Greek sailors in their long distance trips would boil seawater in a brass vessel and suspend large sponge on top of it to absorb the vapors. The water extracted from the sponge was found to be potable, Kaligirou (2005).

The role of desalination in solving world's water scarcity cannot be overemphasized. With water scarcity mankind has tapped into other sources such as seawater and brackish water. Through the process of desalination, situations of water shortages have been alleviated in many countries. Unfortunately as desalination technologies get cheaper and more efficient, energy cost are rising with dwindling oil supplies. Hence, the search for renewable energy sources (RES) as a means to reduce the reliance on traditional non-renewable energy sources like fossils fuels for desalination processes and attempt to decrease desalination cost continues. The use of fossil fuels also brings about environmental problems, not being limited to global warming but also air pollution, ozone depletion and acid precipitation, Kalogirou (2003).

Solar distillation has been practiced for a long time. The earliest documented work is that of an Arab chemist in the 15^{th} century. Seawater is enclosed in a V- shaped glass roof. As sunlight passes through it, it's absorbed by the blackened bottom of the basin. Seawater is heated and evaporation occurs. The vapor is collected on the underside of the V- roof. The solar still is acting as heat trap because sunlight is transparent to the roof but is opaque to the infrared radiation emitted by seawater as it heats up. This method requires a relatively small initial investment and is suitable for small scale purposes. However, there are few solar distillation plants operating today because the space consuming and production of freshwater is limited, Hawlder and Malek (1992).

The world is facing an urgent problem and that by 2015, 40% of the world population will be living in regions without adequate fresh water supply. Presently, almost all sea water desalination plant is electricity based and highly power intensive. With more than half of the world likely to become dependent on sea water desalination such an energy-expensive scenario will be clearly unsustainable Tiwari and Tiwari (2008). This work provides recent information on various practices, developments and improvements in water distillation, heat and mass transfer and solar distillation in today's world.

Water may be considered a more important resource than energy given that water crisis is life threatening. However, freshwater may be produced from seawater or brackish water using energy. Large scale sea water desalination processes are discussed and an example project on the Persian Gulf coast is described. For small scale fresh water production, basin type solar stills are viable options, Bahadori (2005). Such stills may be designed to meet an individual family's needs or the needs of small villages scattered in southern part of Iran.. Based on the design and operating conditions, solar stills may produce 3-6 liters of freshwater per square meter per day, with an estimated average production rate of 1.5 cubic meters per square meter per year for the southern region of the country, Bahadori (2005).

Trieb, (2007) did a project on concentrating solar power for seawater desalination highlighted that all Middle East and North Africa(MENA) countries have an outstanding potential for solar energy hence concentrating solar power plant to power desalination either by electricity or in combined generation with process steam to solve water scarcity problem is rather an obvious approach. In some of his preliminary results he discovered that population growth and economy, increasing urbanization and industrialization and rather limited natural resources of potable water are leading to serious deficits of freshwater in level many parts, increased use of desalted water is therefore unavoidable in order to maintain a reasonable level of water supply. Desalination of seawater based on fossil fuel is neither sustainable nor economically feasible in a long term perspective as fuels are increasingly becoming expensive and scarce. Concentrating solar power offers a sustainable and economically competitive method of desalination.

MENA region is faced with poor management of water, inefficiencies use of water in agriculture where irrigation uses upto 81% of extracted water and overexploitation of fossils aquifers to meet growing demand while water resources decline. To meet this demand desalination is on the rise in MENA countries although it is costly and energy intensive, World Bank (2012). Countries in this region recognize these challenges and hence are working to improve the water use efficiencies and increasingly building renewable energy alternatives as an additional source of power. In fact, MENA countries are planning to increase shares of renewable in their energy portfolio by 5-40% by 2030. The region is already a global leader in both desalination and renewable energy technologies mainly solar. The viability of desalination powered by renewable energy needs to be assessed from the economic, social, technical and environmental viewpoints to make it a competitively viable option hence changes in policy, financing and regional cooperation are paramount, World Bank(2012).

Yates and Woto (1990) wrote a paper on solar powered desalination and specifically focused on Botswana. The paper found that in Africa chronic drought conditions are reducing access to quality drinking water in Botswana. Recurring droughts have left 80% of the population reliant on water from boreholes. Drilling boreholes is often an expensive undertaking and the water is often saline. The paper suggested that one possible solution to this dilemma is solar desalination. Further, the paper summarizes results of an intensive 3 year study by two NGOs on the technical performance and suitability of small scale desalinators. It was found out that small scale desalinators can provide a constant and adequate supply of clean water and that the technology is readily acceptable to remote area dwellers. This is one of the reasons for its consideration in the present study.

A report prepared for the World Bank by a consortium of consultants in 2004 concludes that desalination alone cannot deliver the promise of improved water supply. The best use of desalination is subject to other wider water sector related conditions. In some countries water utilities, politically determined low water tariffs, high water losses and poor sector policies means that desalinated water may not be used wisely. It is preferable not to engage in desalination on large scale unless underlying weaknesses of water sector are addressed. It also concludes that desalination technology has evolved substantially making it cheaper, more reliable, less energy intensive and more environmentally friendly than years ago. It has the potential to contribute to the alleviation of global water scarcity.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

This chapter describes and discusses the study area, research design and methodology employed in this study. The chapter also justifies and explains the choice of the methodology applied in conducting the study as well as highlighting details of the research design, target population, sampling design and technique, data collection instruments, analysis and presentation.

3.1 The Study Area

3.1.1 Physical Background

This section explains the physical environment of the study area which includes location, topography, climate, geology, soils and water resources.

3.1.1.1 Location of the study area

Mombasa County is situated in the southern part of the Coast region. It's the smallest of the seven Counties in the coast region covering an area of 299.6km excluding 65km of water mass. Its borders Kilifi County to the North, Kwale County to the Southwest and the Indian Ocean to the East. The County lies between latitudes 3^{o} 80" and 40^{o} 10" South of the equator and between longitudes 39^{o} 60" and 39^{o} 80" East of the Greenwich meridian. Administratively, Mombasa County shares the same boundaries with the local authority, the Municipal council of Mombasa. The County is divided into four divisions which are subdivided into 18 locations and 30 sub locations as indicated in table 3.1

Division	Area km^2	Locations
Island	14.1	7
Changamwe	54.5	5
Likoni	51.3	3
Kisauni	109.7	3
Total	229.6	18

Source: Mombasa District Development Plan (2009)

Table 3.1: Mombasa County Divisions

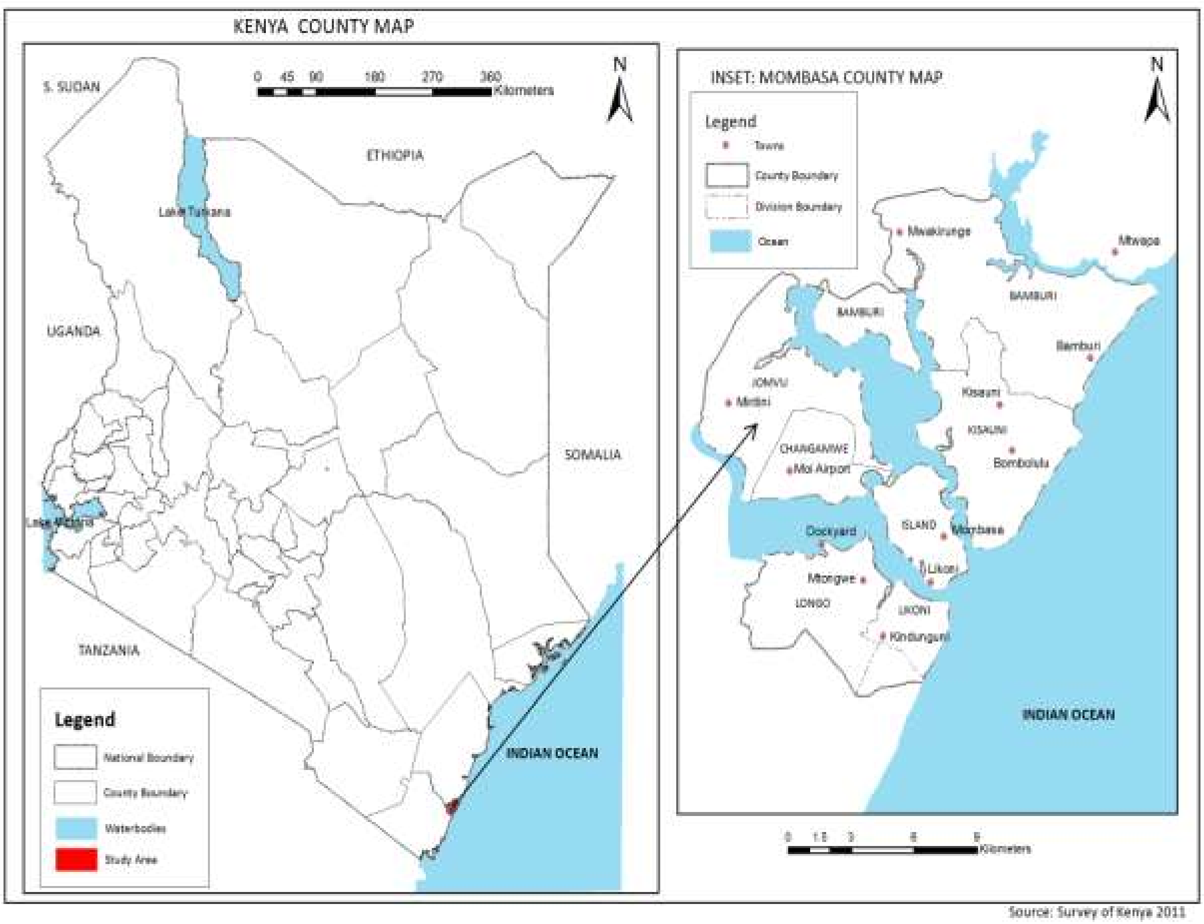


Figure 3.1 Location Map

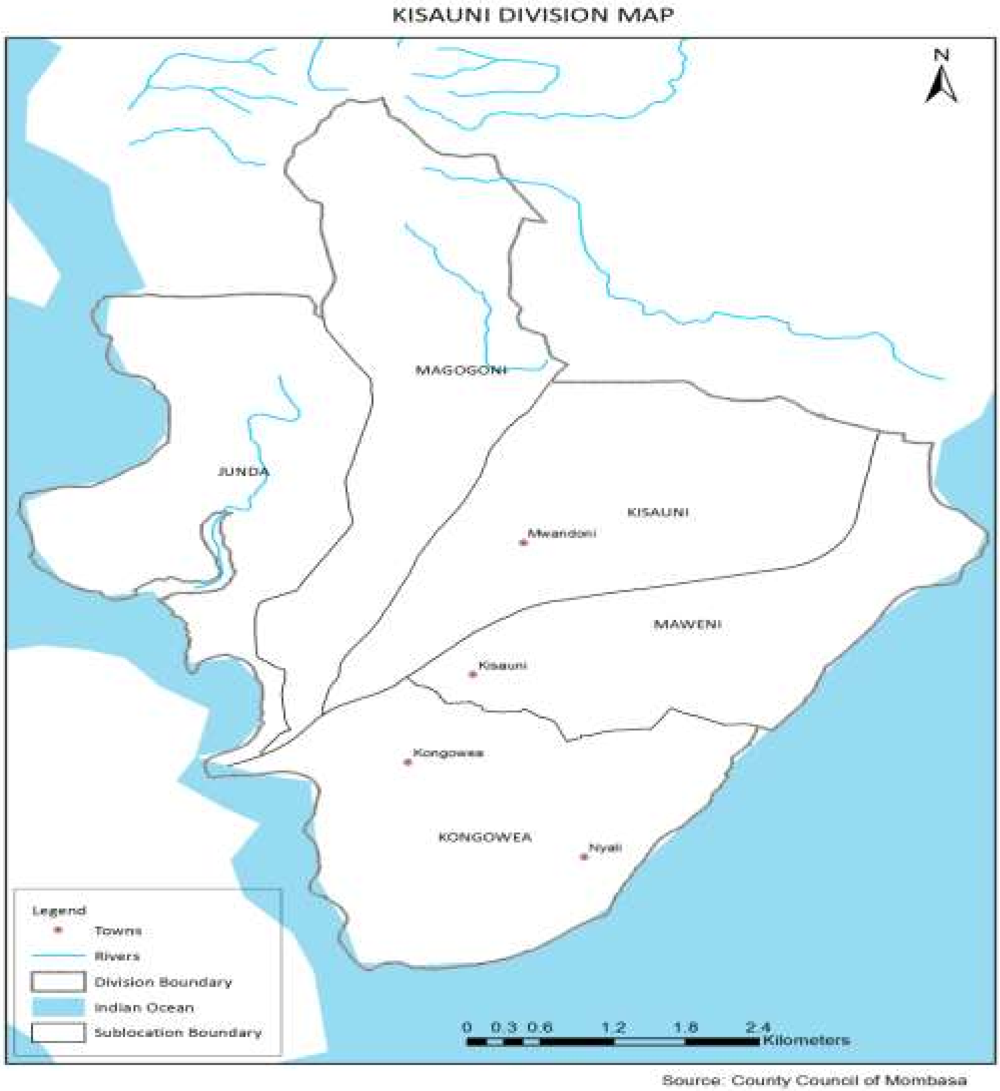


Figure 3.2 Map of Kisauni

3.1.1.2 Topography

Mombasa County lies within the coastal lowland which rises gradually from the sea level in the East to slightly over 76.2m above the sea level in the mainland west. The highest point is found at Nguu Tatu hills in the mainland north that rises to 122m above the sea level.

The Mombasa County has three distinct physiographic units. The coastal plain which is found close to the sea covers parts of south coast and the Island covering parts of

Changamwe and parts of North Coast areas of the county. The coastal plain is 4-6 km wide and lies between the sea and about 45 m above sea level. The coastal plain consists of extensive flat terrain dominated by a series of raised beach terraces underlined mainly by coral limestone and sand deposits which are well drained, firm ground with good foundation conditions with relatively good ground water yields and a source of construction materials.

The hilly, severely dissected and eroded terrain that is found within the western parts of the county is another physiographic unit. The area is underlain by shales and rises generally from about 45m to 122m above sea level. The shales wither into generally poorly drained and easily eroded clay soils which contain little or no soil moisture. This together with rugged terrain attracts little settlement and discourages development of infrastructure. Agricultural activities are the main land use activities. The third physiographic unit is the Ocean and the shorelines.

Other features include the Indian Ocean, the fringing coral reef and cliffs, the island, ports and harbors, creeks, tidal flats and sandy beaches. These features are as a result of interaction between the existing geological conditions and natural processes such as sea level changes, erosion and deposition.

The County is underlain by Jurassic to recent age sedimentary rocks. During Pleistocene to Recent times numerous fluctuations in the sea level led to the evolution of the present coastal configuration. Lowering of the sea level led to severe erosion and down cutting of the river valleys draining into the sea while subsequent rise in the sea level led to submergence of the valleys and the creation of Mombasa Island surrounded by deep natural creeks, ports and harbors.

Generally, the flat topography influences surface runoff because water stagnates giving it ample time to infiltrate and percolate recharging groundwater aquifers.

3.1.1.3 Geology

Sedimentary rocks of Jurassic to Recent age underlie the county. The county is located on the coastal lowland with extensive low-lying areas rising from 8m above sea level in the east to about 100m in the west. The Island and Kisauni area are basically flat alluvial plains. Near the sea, the land is composed of Pleistocene coral reef (Ojany and Ogendo, 1973) which is commercially exploited as a source of limestone for cement industry and also as a source of building stones. The seashore has extensive sandy beaches which makes the town an attractive tourist destination. The geological structure of sedimentary rocks promotes rapid infiltration and percolation of rainwater to recharge groundwater aquifers (ICZM, 2011). This is a factor why brackish groundwater sources were part of the investigations in the present study.

3.1.1.4 Climate

Mombasa County lies within the coastal strip in the hot tropical region where the weather is influenced by monsoon winds. The total annual rainfall varies between 1015mm-1270 mm with a mean rainfall of 1040 mm. The rainfall pattern is characterized by two distinct long and short seasons corresponding to changes in the monsoon winds. The long rains occur between March and July with average of 655 mm with a peak of 330 mm in May and correspond to the south easterly monsoon winds. The average total annual rainfall has reliability of 60%. The short rains start towards the end of October until December and correspond to the North Easterly monsoon winds which are comparatively dry. The short rains average is 240 mm with a peak of about 100 mm in November. This rainfall is important in recharging of groundwater aquifers hence maintaining the water table.

Availability of rainfall data is important for quantification of the recharge rate to groundwater aquifers for efficient groundwater resource management.

The annual mean temperature is 26.4^{o} C with a minimum of 21^{o} C and a maximum of 32^{o} C. The hottest month is February with a maximum average of 32^{o} C while the lowest temperature is in July. Average humidity at noon is about 65%. The hot temperature found here causes high rates of evaporation resulting to lack of reliable surface water in the county. However, the high temperature and sunny climate is suitable for solar desalination using solar stills.

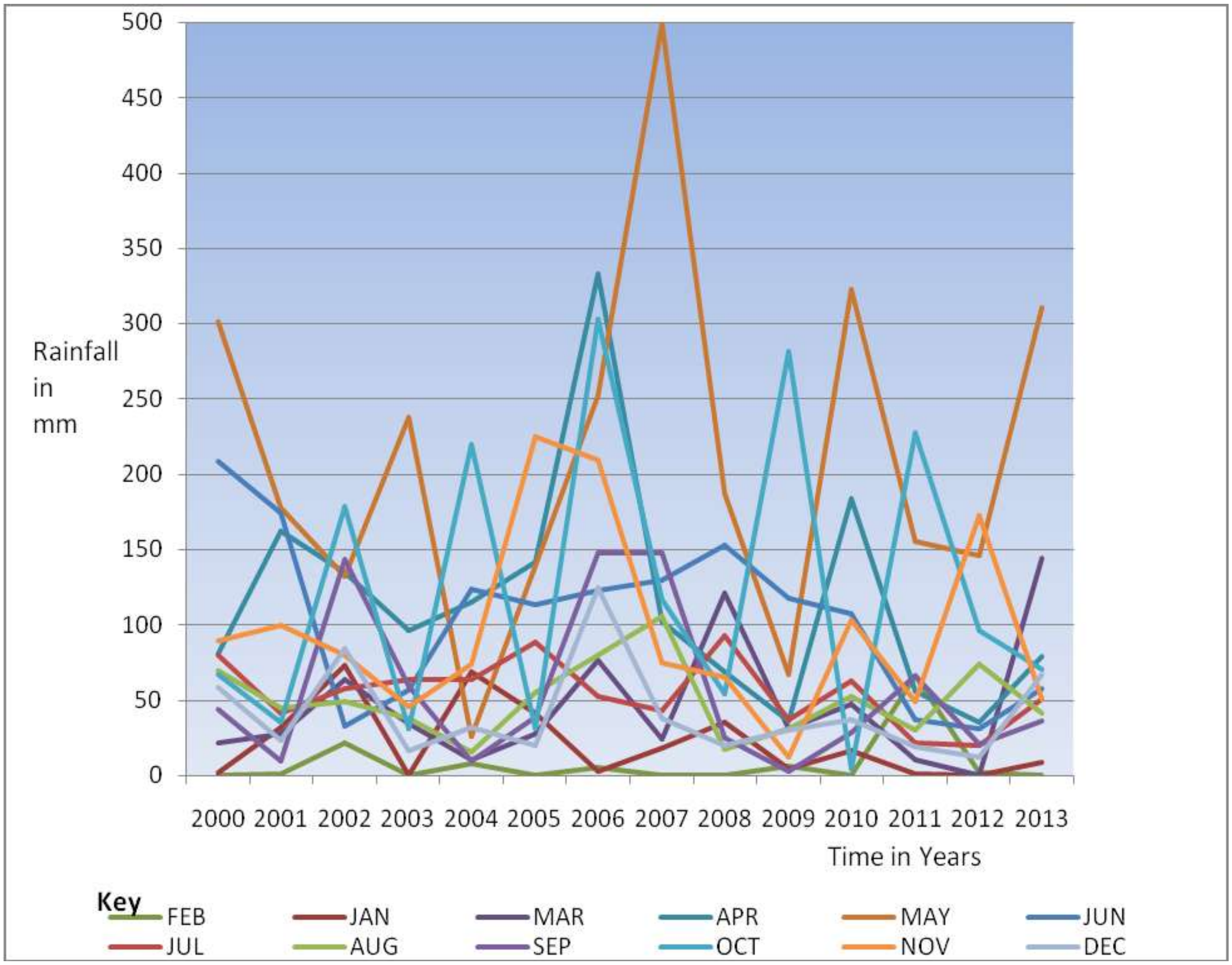


Figure 3.3: Monthly Precipitation Variations 2000-2013

Source: Kenya Meteorological Department (2012), **Station**: Moi International Airport

3.1.1.5 Soil

The soil types are broadly associated with the geological formations along the physiological zones in the county (Ministry of Agriculture 1988). Along the coastal lowlands four soil types predominate.

On the reefs along the shore well drained shallow to moderately deep loam to sandy soils predominate, on the unconsolidated deposits in the Quaternary sand zone (also known as Kilindini sands) are well drained deep sandy clay loam to sandy clay soils underlying 20 cm to 40 cm of loamy medium sand, also found are areas with very deep soils of varying drainage conditions and color, variable consistency, texture and salinity and well drained very deep, dark red to strong brown firm, sandy clay loam to sandy clay underlying 30 cm to 60 cm medium sandy to loamy sand soils.

On the coastal uplands composed of raised areas in Changamwe and Western parts of Kisauni, two soil types dominate. Soils developed on unconsolidated sandy deposits in the Magarini formation composed of sandy to loamy soils. These are well drained, very deep, sandy clay loam to sandy clay loam to clay with a top soil of fine sand to sandy loam and Soils developed on shale composed of heavy texture constitute the relatively high agricultural potential in the county. The soils are dominated by well drained shallow to moderately deep, firm to very firm clay and imperfectly drained deep, very firm clay with humic topsoil and sodic deeper subsoil.

Soil types found here allow easy infiltration and percolation of water to the unconfined aquifers hence recharging groundwater.

3.1.1.6 Water Resources

Mombasa County like many other towns in Kenya receives its water supply from distant areas. Its main source of water supply is in the Mzima springs found 300 km away in Chyulu hills. These springs are believed to be part of the Kilimanjaro mountain system which generally falls under the Athi River drainage basin, generally referred to as Sabaki when enters the coastal zone.

Apart from the Mzima springs, the county and the coastal region in general receives surface water supplies from Baricho, Marere and from the Tiwi boreholes in the south coast area. Generally, Mombasa County receives 130,000 cubic meters of water against a demand of 200,000 cubic meters daily according to NWCPC (2000).

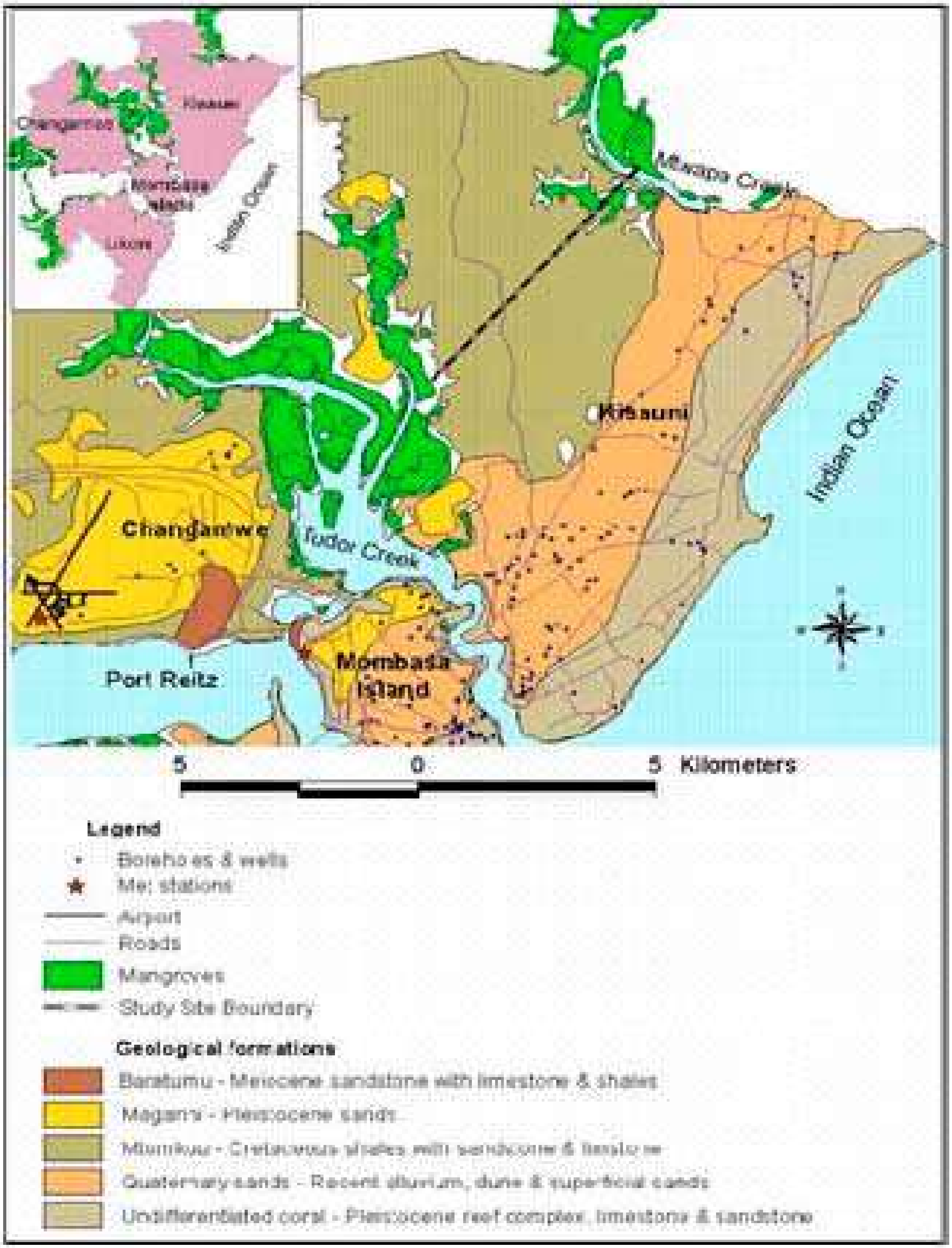


Figure 3.4 Water Sources **Source: Mwanguni 2002**

From the onset Mombasa and the coast has encountered persistent water problems due to many factors but mostly due to population increase and poor maintenance of existing water supplies networks. Though the area is geologically rich in groundwater with about 50 boreholes and 25 wells according to Mwanguni 2002, utilization is limited due to salinity caused by sea water intrusion as a result of over exploitation, presence of pit latrine and poorly kept septic tanks.

3.2 Socio-economic Background

This section highlights population characteristics, the main industrial and commercial activities in the study area.

3.2.1 Population Characteristics

Table 3.2 shows population distribution and settlement pattern in the county between the three most recent census periods. The island was the most populated in 1989 followed by Kisauni and Changamwe but the pattern changed by 1999 with Kisauni being the most populous followed by Changamwe and the Island taking third position mainly because of availability of cheap housing. In 2009 Kisauni continues to be the most populous because of availability of cheap housing. The Island still has high density because the area is too small and the population is increasing leading to congestion.

Population distribution and settlement pattern in the county are influenced by infrastructure network such as roads, water, electricity, availability and accessibility of areas of gainful employment, availability of cheap housing, security and land tenure systems.

High population densities are found in island Division and along the major highways such as Lunga-Lunga road in Likoni division, Mombasa – Nairobi road in Changamwe division and Mombasa – Malindi road in Kisauni division. These areas are well served with infrastructural services. Sparsely populated areas are found at the outskirts of the county. These are Mwakirunge, Maunguja, Mwangala and Makupa jetty area. These areas are least developed in terms of infrastructure such as road network, electricity and water supply.

As the population continues to grow more pressure is exerted on the available water resources because of the increase in demand for water. This means that pollution of available water resources is also high because of waste being produced with inadequate waste management strategies.

Division	Pop 1989	Pop 1999	Pop 2009	Density 1989	Density 1999	Density 2009
Island	127,720	146,344	74,735	6,082	10,379	12392.6
Kisauni	153,324	249,861	405,930	1,217	2,278	3544.7
Likoni	67,240	94,883	176,426	1,051	1,850	4083
Changamwe	113,469	173,930	282,279	1,598	3,191	5.35124

Table 3.2: Population Distribution of Mombasa County

Source: KNBS (2010)

3.2.2 Industrial and Commercial Activities

Bamburi cement remains the single largest industry in the area and continues with programs of rehabilitation of the abandoned coral limestone quarries. The rehabilitated quarries have since been converted into nature parks doing business in ecotourism and fish farming (UNEP 2005).

Another landmark feature for the economy of this area remains the Kongowea market trading in all types of food stuff and second hand clothes. The clothes in the market periphery have emerged to be a large business attracting large population into the area. Despite the increase in human traffic sewage management systems have not been upgraded to cope with the rising demand. Unpleasant odors at the market are common due to uncollected rotting garbage and poor sanitation hence sanitation is an issue of major concern in the market. (UNEP 2005)

3.3 Conceptual Framework

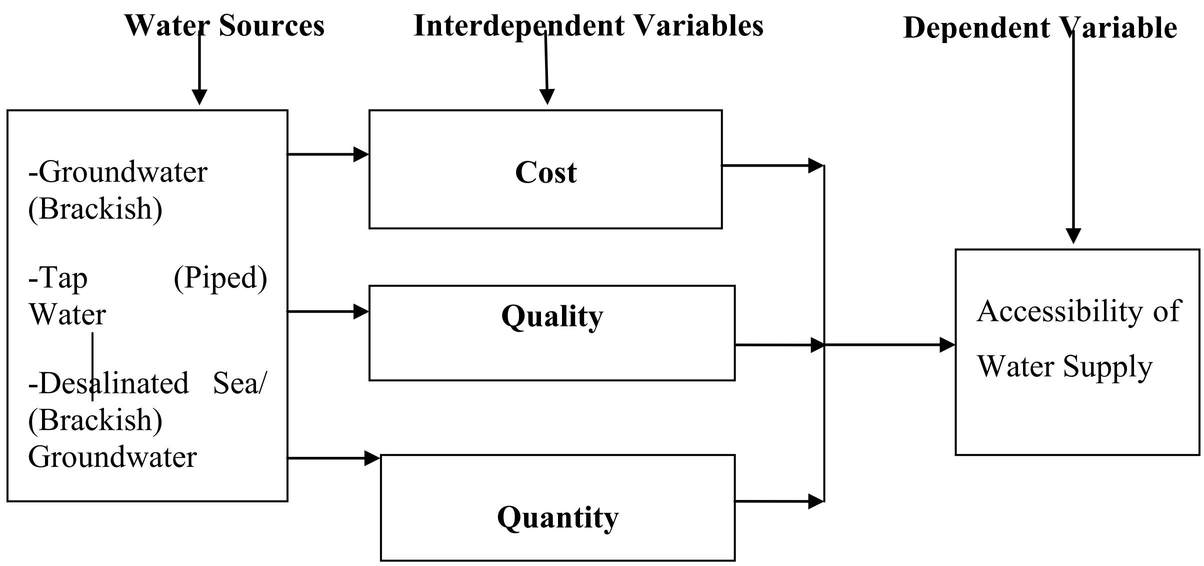


Figure 3.5 Conceptual Framework

The water sources are all affected by interdependent variables that are cost, quality and quantity. Interdependent variables because change in either of the variable triggers a negative or positive change on others, they are mutually reliant on each other. Dependent variable (accessibility of a water supply option) is a function of all interdependent variables; accessibility is reliant on all of them.

3.4 Research Design

The research design used in the present study is a case study. Kothari (2008) defines a case study as a method used to narrow down a very broad field of research into an easily researchable topic. The design is particularly suitable for the study because the findings are intended to reflect the effects of cost, quantity and quality in determining the accessibility of a water supply in the wider Mombasa region and its environs. To gather qualitative and quantitative data for analysis and interpretation to answer the research questions and to obtain the current situation concerning the accessibility of water supply, the study used both descriptive and analytical approach as the former determines and reports the way things are and attempts to describe such things as possible behavior, attitudes and values (Mugenda and Mugenda 2003) and the latter explains with reasons why such things happen.

3.5 Population Characteristics of the Study

The population of this study was the households that are found in Kisauni area and are affected by cost, quality and quantity in their daily use of water. According to the 2009 Population & Housing Census, Kisauni constituency had a population of 405,930 which constituted 112,331 households. This constituted the target population for the study.

3.6 Sample Size and Sampling Technique

The sampling technique that was used in this case study was simple random sampling to select the required sample where every household had an equal chance of being selected.

Though it is always maintained that the rule of thumb is to obtain as big sample as possible, the resources and time being a major constraint the following formula was used to determine the sample size where the target population was more than 10,000 people as in the present study.

The sample size was arrived at using the Fishers test (1998)

$n = Z^2 pd / d^2$ -- (i)

Where: **n** is the sample size

Z is the standard normal deviate (1.96), at 95% confidence level.

p is the proportion of the target population estimated to have a particular characteristic

d is the level of statistical significance (Mugenda and Mugenda 2003)

At a confidence level of 95% (Z=1.96) and a statistical significance set of 0.05 is

$\mathbf{n} = \underline{(1.96)^2 (0.5) (0.5)}$

$\mathbf{n} = (1.96)^2 (0.05)^2$

$\mathbf{n} = 384$

According to equation (i) the study sample obtained was 384 respondents.

3.7 Data Collection Procedures and Instruments

According to Kothari (2008) information obtained by means of questionnaires is free from bias as the person conducting the research cannot influence the respondents hence accurate and valid data can be obtained. They are also cheaper, easier to administer and convenient as the respondents are given time to fill in the questionnaires. This study used questionnaires to collect data on cost and quantity of water accessed by the respondents. The questionnaires were randomly distributed depending on the willingness of a household to participate in the study.

A sterilized plastic water sampler was used to grab water samples from the taps and scoop water samples from wells. A total 9 water samples were collected, 3 samples for tap water and 6 samples for groundwater from wells that were mostly used by residents. The taps that were sampled were selected randomly depending on the availability of water. The samples were stored in a cool box while being transported to the laboratory.

A simple solar still was used to desalinate brackish groundwater and seawater. A solar still measuring 1.2m wide, 0.6m long and 0.6m above the ground was constructed by use of clear glass at the top and metal sheet to create a basin that was painted black inside. The basin was sealed airtight by the glass which was set at an angle (45˚) so that it was slanting. This way, when the basin was filled halfway with seawater or brackish water it began to evaporate, until the vapor inside got saturated and condensation occurred at the coolest surface available, the glass. Since the glass was set an angle the condensate flowed down rather than drop back into the basin. Clean water was then collected in the gutters at the lower edge of the glass.

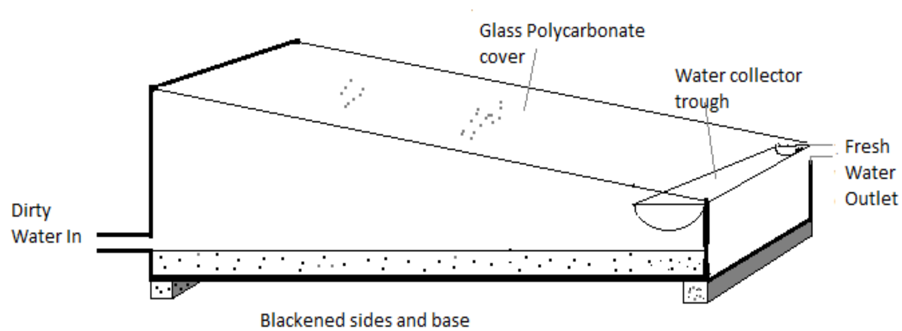


Figure 3.6: Solar still Concept

Source:Modified from Charl 1993

To obtain high efficiency of the solar still, the construction was objectively designed to maintain high feed (seawater or brackish) temperature, low vapor leakage and large temperature difference between feed water and the condensing surface (the glass)

A high feed temperature was achieved by high proportion of incoming radiation being absorbed by feed water as heat, hence low glazing and good absorbing surface by painting the basin black, heat losses from the floor and walls was minimal because of the airtight conditions and water being shallow to heat quickly. A large temperature difference between feed water and condensing surface (the glass) being a poor conductor of heat hence absorbing little or none of the incoming radiation and condensing water dissipating heat which was removed rapidly from the condensing surface because of slanting glass.

The brine that remained in the basin was flushed out as often as it was necessary and was exposed in the sun to evaporate the remaining water and leave behind salt. The output of a solar still can be approximated using the following estimating method

Q=E+G+A/2.3 -- (ii)

Where

Q - Daily output of desalinated water (liters/day)

E - Overall efficiency (normally given as 30% -40%)

G - Daily global solar irradiation (mj/m) a typical country on average daily global solar irradiation is typically 18.0 mj/m.

A - Aperture area of the still (the plan area for a simple still) in this case (1.2m × 0.6m× 0.6m).

3.8 Water Quality Analysis

Water quality analysis of the collected water samples was done at Coast Water Services Board laboratory. All the three categories of water parameters namely physical, chemical and biological parameters were analyzed and the results compared to WHO (2010) drinking water standards to determine the suitability of water supply options available in terms of quality. The following water quality analysis methods were used.

3.8.1 Field Analysis

Field analysis methods were conducted to non-conservative water quality parameters since they change with time. The physical parameters that was analyzed under this method were smell or Odor and color – shall not be offensive to consumers. This was evaluated through qualitative observation and smelling the water and if contamination is indicated then testing was done to confirm water quality.

3.8.2 Laboratory Analysis

Laboratory analysis methods were carried out immediately the samples reached the laboratory. The analysis was done within 24 hours. These parameters include physical, chemical and biological parameters. The physical and chemical parameters and their units include,

1. Turbidity - NTU
2. pH – pH scale
3. Total Alkalinity
4. Magnesium - mg/l
5. Calcium - mg/l
6. Salinity - mg/l
7. Total Hardness - mg/l
8. Chloride - mg/l
9. Total Dissolved Solids - mg/l
10. Conductivity - µs/cm (a measure of mineral salts in water, water conductivities above 2000 µs/cm are said to be saline).

Although fluoride is an important parameter in drinking water it was not done here because its distribution and concentration is similar to that of fluoride rich volcanic rocks, since the coast does not have volcanic rocks fluoride in its waters is almost negligible (Nair, Manji and Gitonga 1984).

These parameters were analysed using colorimetric method of water quality analysis.

Indicators of microbial contamination of water, faecal coliforms and E.coli were enumerated by multiple tube method of the Most Probable Number (MPN).

3.9 Data Analysis and Presentation of the Findings

Based on the questionnaires both qualitative and quantitative data was generated. Descriptive and analytical statistics was then applied to analyze the data through the use of Statistical Package for Social Science (SPSS). This was appropriate as it was possible to calculate percentages, averages and frequencies presenting them in form of charts and graphs and to analyze the relationship of each variable to accessibility of water supply. It was also possible to test the hypotheses that were earlier formulated.

The analysis results from water quality analysis were compared with the acceptable WHO drinking water standards to determine the suitability of water from the sampled sources for human drinking purposes as well as other domestic uses.

The solar still was then used to desalinate brackish groundwater and seawater to eliminate shortcomings encountered by both water sources in terms of cost, quantity and quality.

The overall results and the findings were used to determine the most accessible water supply for Kisauni residents in Mombasa County in terms of cost, quality and quantity. The results were also used to make recommendations to various stakeholders and to point out areas for further research.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter presents analysis and findings of the study as set out in the research objectives and methodology.

4.1 Demographic Information

This section discusses the household size, water consumption and the relationship between them as well as household water sources.

4.1.1 Household Size

The study sought to establish the household size of families living in Kisauni Mombasa. From the findings, majority of the households (69.3%) had 1-5 members, 25.3% had 6-10 members while 5.3% had 11-15 members. (Table 4.1)

Number of People	**Frequency**	**Percent**
1 – 5	208	69.3%
6 – 10	76	25.3%
11 – 15	16	5.3%
Total	**300**	**100.0**

Table 4.1.1: Household Size

This shows that most of the households in Kisauni constitute a maximum of 5 members implying that small scale solar powered desalination of seawater or brackish water is appropriate to such households in improving the quality of water they access with minimal cost being incurred because the quantity required by 5 members household is not prohibitive because 50% require 51-100 liters or five 20liter jerricanes.

4.1.2 Household Water Consumption

The respondents were asked to indicate their household water consumption per day. According to the findings 50% of the households consumed 51–100 litres of water, 18.3% consumed 1–50 litres, and 12.7% consumed 151–200 litres while 11.7% consumed 101–150 litres respectively. In other terms most of the households averagely use five Jerricans of water daily for their domestic use hence it's easy to access such quantity of water from improved solar powered stills at very improved quality and manageable cost.

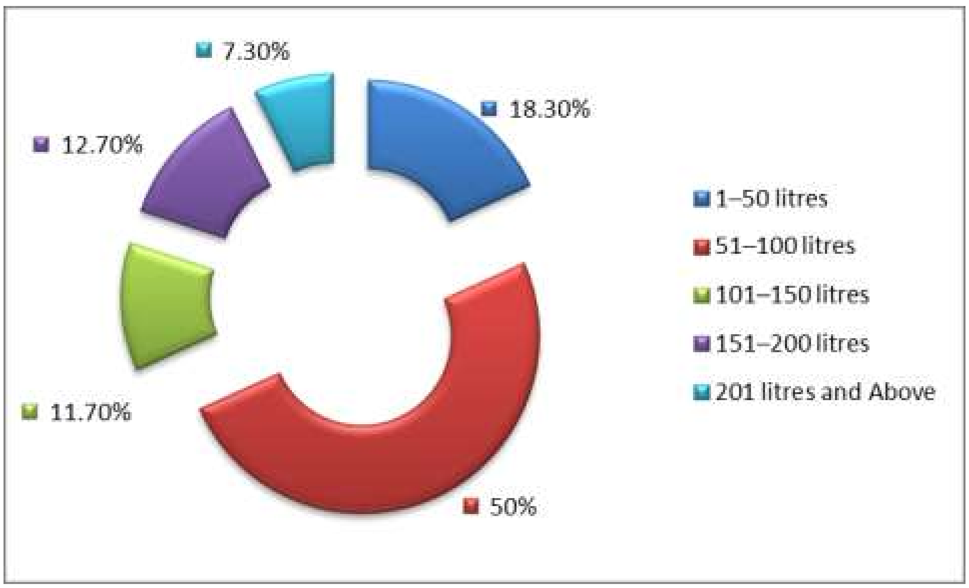


Figure 4.1: Household Water Consumption

4.1.3 Household Size and Water Consumption.

In trying to establish the relationship between household size and water consumption, the study further sought to correlate data on household size and water consumption (Figure 4.2). These findings depict that household size determined the quantity of water consumed by a household whereby the smaller the size of the family the lesser the quantity of water they consumed and the larger the household the larger the amount of water they used.

This implies that the higher the quantity used, the higher the cost of accessing it. This means that large poor families that need to access large amount of water end up using the cheaply available water sources that in most cases are of poor quality hence this may have some health implications.

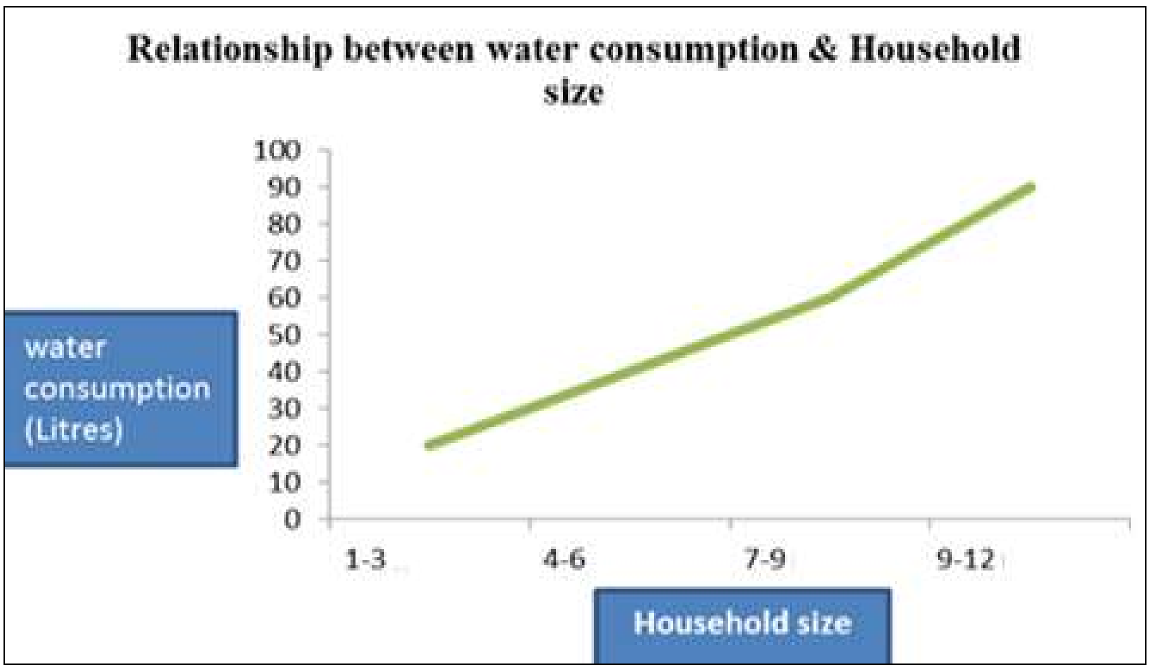


Figure 4.2: Household Size and Water Consumption

4.1.4 Household Water Sources

The study respondents were requested to indicate the sources of water that they had access to. From the results, 44.1% of the respondents use tap water, 26.2 % use groundwater while 29.7% use both groundwater and tap water. These percentages clearly indicate that residents cannot access the best water supply in terms of cost, quantity, and quality from one water source resulting to using both water sources to compliment the shortcomings of the other. Otherwise, the percentages of the most accessed water supply would have been well over 50%.

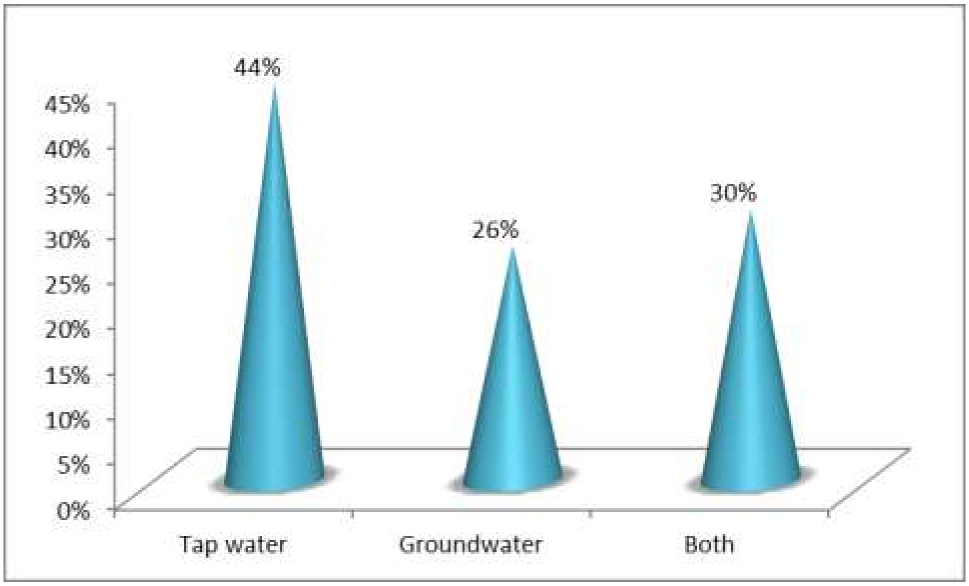


Figure 4.3: Household Water sources

4.2 The effect of cost in accessing water

The first objective of the study was to determine the effect of cost in accessing water. This objective seeks to understand how cost affects the quantity and the quality of water accessed.

4.2.1 Rating the cost of water from various sources

The study requested the respondents to rate the cost of water that influenced accessibility of water from different water sources. The findings indicated that on tap water; most of the respondents (43.3%) rated the cost as high (Kshs 250- Kshs 500 per month), 35% as very high (above Kshs 500 per month), 14% as fair (Kshs 100-kshs 250 per month) while 7.7% rate tap water as low (<Kshs 100 per month). The findings indicate that the cost of accessing tap water as being very costly and hence majority of the residents cannot afford to use tap water as the most accessible water supply option.

On the other hand, 40.3% of the respondents rated the cost of groundwater as low, 32% as fair, 20.7% as high while only 7% rated the cost of groundwater as very high (Figure 4.4). This indicates that groundwater was relatively less costly and majority of the residents could access groundwater while the cost of tap water was much higher than that of groundwater. Thus, the high cost of water tends to limit its accessibility as a water source.

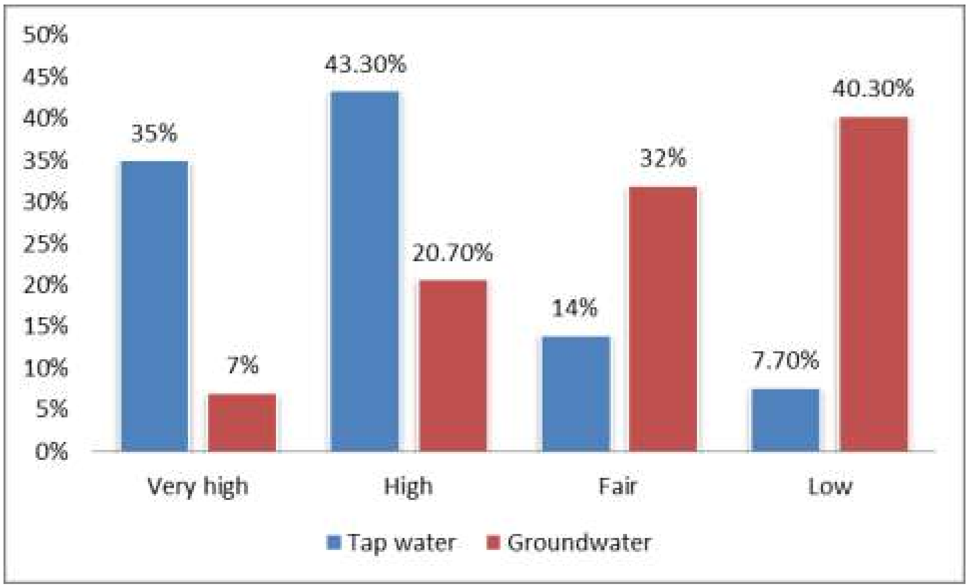


Figure 4.4: Rating the cost of water from various sources

4.2.2 The cost of water and the quantity of water

The study further sought to establish the influence of cost of water on the quantity of water accessed by Kisauni residents. From the findings, the study established that the quantity of water accessible to the residents in Kisauni was determined by the cost of water. As the cost of accessing water increase water consumers try to minimize on their consumption to avoid spending more on the important commodity. This implies that the higher the cost the smaller the quantity used.

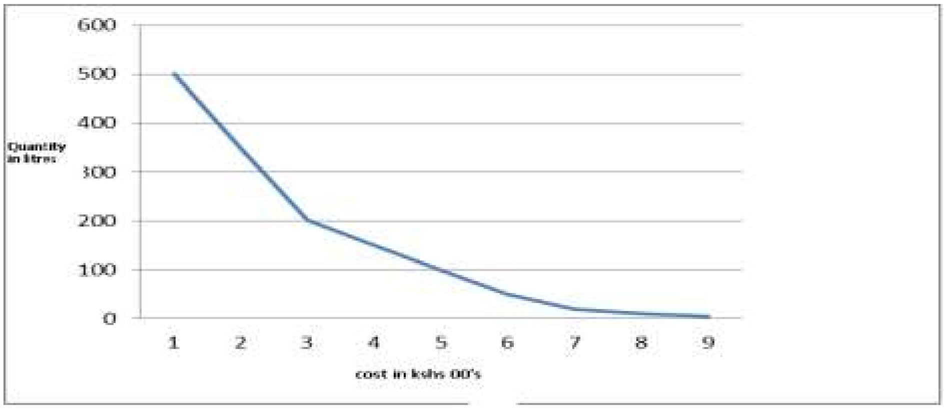


Figure 4.5: Relationship between Cost and Quantity of water accessed

4.2.4 The Cost of Water and the Quality of Water

The study also tried to establish the influence of cost of water on the quality of water accessed by Kisauni residents. According to the results, the higher the quality of water accessible to the residents, the higher the cost and the reverse is true. The majority of the respondents could not afford high quality water due to the high cost of accessing it.

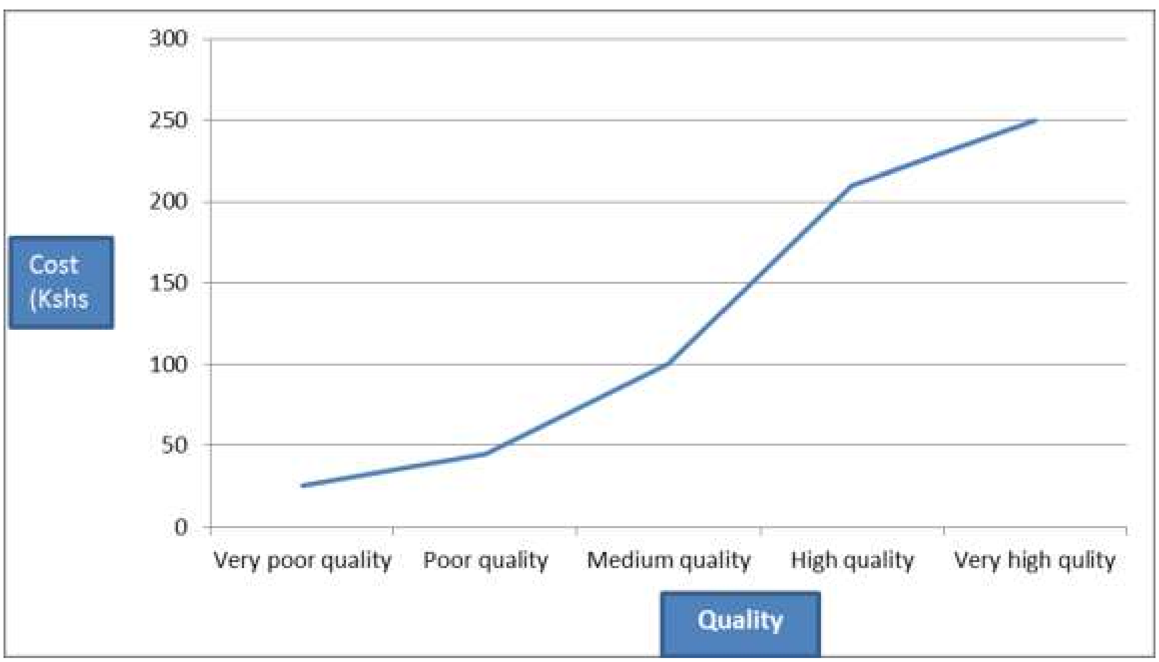


Figure 4.6: Effect of Cost on Quality of water accessed

4.3 Accessibility of good quality water to Kisauni Residents

The second objective of the study was to investigate whether good quality water is accessible to Kisauni residents. This involved testing the water quality of water obtained from sources used by Kisauni residents.

4.3.1 Water Quality

The study was interested in establishing from the respondents the quality of water they use. According to the findings, most of the respondents (44.3%) argued that the quality of water that they had access to was of poor quality (cannot be used without treatment), 34.7% argued that the quality of water was low (can be used without treatment but with health complications) while 15% argued that the quality of water that they had access to was high (used without treatment and no health complications). Most of the respondents use poor quality water because that's what they could afford while few of them could afford high quality, this being a low income settlement.

4.3.2 Quality of Tap Water in Kisauni Mombasa

In order to further assess whether good quality tap water is accessible to Kisauni residents, the researcher conducted water samples analysis of tap water used in Kisauni Mombasa County. According to the findings, tap water in Kisauni is characterized by low levels of access as well as poor service quality in terms of intermittent supply.

In reference to water quality analysis for tap water in Kisauni (Table 4.2), this water can be said to be physically, chemically and biologically fit for human consumption. It is therefore fit to be used for drinking and other domestic purposes without any further treatment because all the analyzed parameters were below WHO specified standards and the presence of harmful bacteria in the tap water was completely absent as required by WHO drinking water standards. This means tap water is of high quality but it is also expensive therefore very few consumers can access it therefore there is need for good quality and affordable water supply.

Physical and Chemical Parameters					
	Unit	**Tap1 From Marere water works**	**Tap2 From Mzima**	**Tap3 From Mzima**	**WHO 2010 Drinking water Standards**
Color	hazen	Clear	Clear	Clear	Max 15
Conductivity	µS/cm	0.007	0.03	0.05	Max 2000
pH	pH scale	7.58	6.9	7.1	6.5 – 9.0
Turbidity	NTU	1	1	1	Max 25
Total Hardness	mg/l	121	70	90	Max 500
Chloride	mg/l	1	14.6	31.9	Max 600
Total Alkalinity	mg/l	39	72	78	Max 500
Magnesium	mg/l	1.4	1.8	0.7	Max 150
Calcium	mg/l	3.4	13.4	21.7	Max 250
TDS	mg/l	65	109	210	Max 2000
Salinity	mg/l	110	98	90	Max 250
Biological Parameter					
General Coliform Counts	MPN/100ml	nil	nil	nil	Nil
E. Coliform Counts	MPN/100ml	nil	nil	nil	Nil

Table 4.1.2: Tap Water Quality in Kisauni Mombasa

4.3.3 Quality of Groundwater in Kisauni Mombasa

In order to further assess whether good quality water is accessible to Kisauni residents, the study sought to find out the physical, chemical and biological (characteristics) parameters of groundwater in Kisauni area of Mombasa County.

From the findings based on the physical and chemical parameters, the groundwater was fairly good for human consumption. However, two chemical parameters that are conductivity and salinity were far above the specified WHO standards (Table 4.3). Conductivity measuring up to 2180 μS/cm and salinity measuring up to 478.5 mg/l against WHO maximum of 2000 μS/cm and 250 mg/l respectively were obtained. This is attributed mostly to seawater intrusion into boreholes due to overexploitation of freshwater aquifers or due to rise in seawater level hence the importance of using solar powered desalinators to remove salt from this water as it will take long time to solve this problem completely.

Bacteriologically, the general coliform measured were as high as 2100 MPN/100ml and1200 MPN/100ml for E. coli. This means that the water is heavily contaminated. The main reason for this heavy contamination is due to use of pit latrines as a means of sanitation in this area. Out of the six wells sampled none produced water that's fit for human consumption. This water cannot therefore be used for drinking purposes without further treatment and could only be used for limited domestic uses if need be.

The poor quality of ground water therefore reduces the accessibility of groundwater as a water source supply option within Kisauni area and the entire Mombasa County.

The role of solar desalination as a treatment method in improving water access in Kisauni was assessed. Small scale solar still desalination that is able to remove the salt in the water, kill all the bacteria in it and hence improving the quality of groundwater at the same time increasing the quantity of water accessed by residents at a very fair and affordable initial and maintenance cost.

	Unit	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	WHO 2010 Drinking Water Standards
Physical and Chemical Parameters								
Color	Hazen	2.5	2.5	2.5	2.5	2.5	2.5	Max 15
Conductivity	µS/cm	1830	2160	2020	2180	2060	1824	Max 2000
pH	pH scale	6.9	6.8	7.2	6.9	7.1	7.2	6.5 – 9.0
Turbidity	NTU	0.73	1.79	1.70	1.27	1.97	1.05	Max 25
Total Hardness	mg/l	300	320	422	350	390	370	Max 500
Chloride	mg/l	184	216	436	158	217	178	Max 600
Total Alkalinity	mg/l	290	325	269	378	350	354	Max 500
Magnesium	mg/l	2.44	20.23	10.56	17.48	9.74	12.2	Max 150
Calcium	mg/l	81	28.4	49.41	48.17	74.9	133.65	Max 250
TDS	mg/l	1021	1100	850	1050	990	815	Max 2000
Salinity	mg/l	361.7	478.5	378	270	315.9	279.7	Max 250
Biological Parameters								
Coliform Counts	MPN/100ml	2100	1600	1200	1800	1000	1440	< 10
E. Coliform Counts	MPN/100ml	760	1000	1200	600	800	480	Nil

Table 4.1.3: Groundwater Quality in Kisauni Mombasa

4.3.4 Comparison of quality of water from different sources

The respondents were also requested to indicate the sources of water that produced good quality water between tap water and groundwater.

	Tap water		**Groundwater**	
Rate	**Frequency**	**Percent**	**Frequency**	**Percent**
Very high	105	35%	21	7%
High	172	57.3%	62	20.7%
Low	23	7.7%	217	72.3%
Total	**300**	**100.0**	**300**	**100**

Table 4.1.4: Comparison of quality of Tap water and Groundwater

Where Very high = No treatment required

High = Can be used without treatment with slight health complications

Low = cannot be used without treatment

According to the findings, the majority of the respondents (57.3%) felt that tap water was of high quality while only 20.7% argued that groundwater was of a high quality. Meanwhile 35% of the respondents attested that tap water was of very high quality while only 7% said that groundwater was of very high quality.

From the findings, the study infers that tap water was far much of better quality compared to groundwater but the only inhibiting factors for its use is the cost of accessing it.

4.4 The quantity of water accessed by Kisauni Residents

The third objective of the study was to find out the quantity of water accessed by Kisauni residents per households.

4.4.1 Household Adequacy of water

The study sought to establish the adequacy of water for the households in Kisauni by asking the respondents to indicate the extent to which the quantity of water was adequate. From the study findings, 44.3% of the respondents reported that the quantity of water available was moderately adequate, 36.7% indicated that the quantity of water was available was lowly adequate, 15% indicated that the quantity of water available was greatly adequate while 4% reported that water available was adequate to a very great extent. This depicts that the quantity of water accessed by Kisauni residents was inadequate to meet their household water requirements. The quantity of water accessed by the respondents affected the viability of an option to be used as a water source in Kisauni area of Mombasa County as indicated in table 15. It's important therefore to supplement these water sources like desalination of groundwater using solar still to reduce the inadequacies.

Water Quantity	**Frequency**	**Percent**
Very Great Extent	12	4%
Great extent	45	15%
Moderate extent	133	44.3%
Low extent	110	36.7%
Total	**300**	**100.0**

Table 4.1.5: Adequacy of water available to households

Where Very Great Extent = water available is more than enough

Great Extent = water available is enough

Moderate Extent= water available is barely enough, Low extent= Not enough at all

4.5 Accessibility of a Water Source

The study also sought to establish the accessibility of a water source among the various water supply options in the area under study. The study findings indicate that, most of the respondents (34.5%) attribute accessibility of a water supply source to its availability. They argued that an accessible water supply should be available when needed. 29.7% argued that water has to be affordable for the residents to consider it as accessible. They argued that they should access water at a cost that they can afford. 24.8% argued that the most important factor for water accessibility is water quality. They argued that the quality had to be good for them to consider it as an accessible water supply source. 9%, however, argued that all these factors mentioned were important for a water source to be considered as accessible. Only 1.3% indicated that knowledge of a water source was important in considering an accessible water source.

Opinion	**Frequency**	**Percent**
Affordability	114	29.7%
Availability	132	34.5%
Quality	95	24.8%
Knowledge of the source	5	1.3%
Management	3	0.7%
Total	**300**	**100.0**

Table 4.1.6: Accessibility of Water Source

4.6 Solar Desalination of Groundwater and Seawater

The study assessed the option of increasing quantity of water available to the residents and to improve drinking water quality at the same time reducing the cost of accessing clean water through the use of the small scale solar still desalination technology

The constructed solar still was approximated to yield 1.97 litres per day. This is approximated using the aperture area of 0.6m by1.2m that was constructed in the field; other factors held constant, however, a bigger still for example, of aperture area 10m by 15m would produce 410 litres of water enough for even two households per day.

On the average the solar still produced 2.35 litres of desalinated water per day for seawater and 5.9 litres from brackish groundwater. This means that brackish groundwater is easier to desalinate than seawater due to less salt in the water and a solar still can produce desalinated water far above the approximated value when desalinating groundwater. The still produced different amount each single day because of variations in climatic conditions such as wind velocity, solar radiation and temperature.

The water desalinated through solar still was of very superior quality. It is completely demineralized hence it has to be re-mineralized for it to be good for human consumption. The study therefore finds use of solar still desalination as a most accessible water supply in terms quality, quantity and cost.

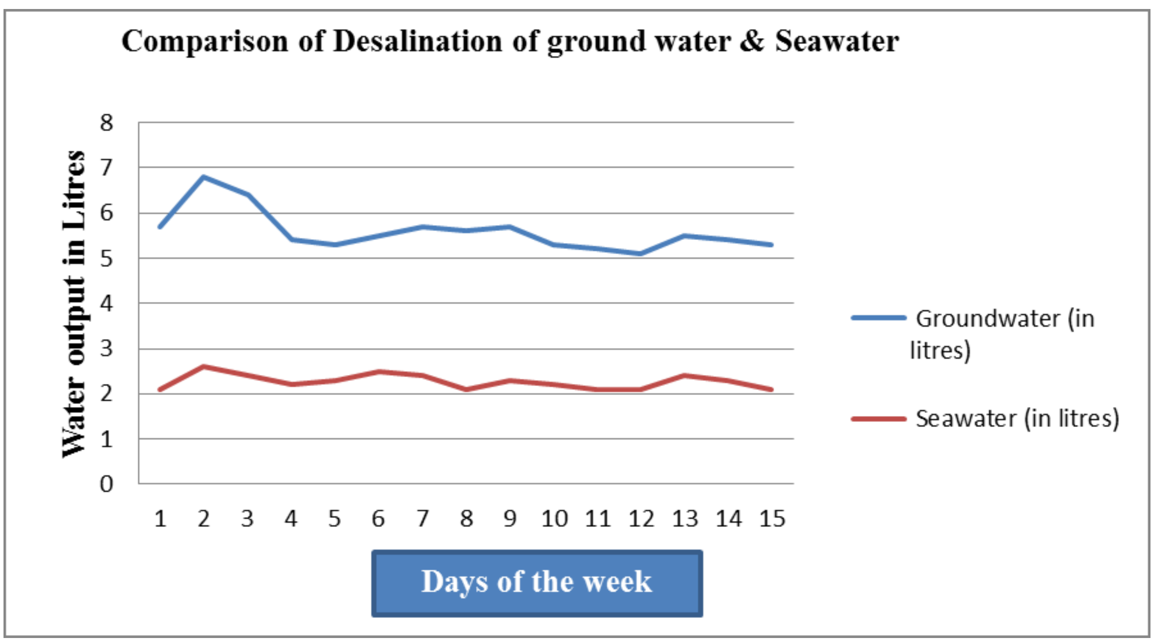


Figure 4.7: Comparison of Desalination of Groundwater & Seawater

The Output (in liters) from groundwater was higher that the Output (in liters) from seawater. From the findings, it can be deduced that it is easier to desalinate brackish groundwater than seawater all other factors held constant. The amount desalinated from the groundwater was greater by over a half (50%) of that desalinated from the seawater from the same 240 litres input of water by the same solar still

Day	Output (litres) groundwater	Output(litres) seawater	**Day**	Output (litres) groundwater	Output (litres) seawater
1	5.7	2.1	**16**	6.1	2.5
2	6.8	2.6	**17**	6.3	2.7
3	6.4	2.4	**18**	5.7	2.7
4	5.4	2.2	**19**	5.8	2.6
5	5.3	2.3	**20**	5.7	2.5
6	5.5	2.5	**21**	5.6	2.3
7	5.7	2.4	**22**	5.4	2.1
8	5.6	2.1	**23**	5.2	2.2
9	5.7	2.3	**24**	5.3	2.4
10	5.3	2.2	**25**	5.4	2.5
11	5.2	2.1	**26**	5.1	2.6
12	5.1	2.1	**27**	5.6	2.6
13	5.5	2.4	**28**	5.2	2.3
14	5.4	2.3	**29**	5.8	2.3
15	5.3	2.1	**30**	5.1	2.1

Average=2.35 litres from seawater, 5.9 litres from brackish groundwater

Table 4.1.7: Solar Still Output

Plate 1: Solar Still Image (a woman admiring the study solar still in her home in Kisauni area of Mombasa County)

This means that with improved materials like using sun resistant slanting glass and improved capacity, this type of solar still can be used to improve the quality of much available brackish groundwater into being more useful without raising the cost above residents capabilities because sun energy is free so it should be adopted to solve water issues in Kisauni and the larger mombasa.

4.7 Hypothesis Testing

The study also set out to test the hypothesis that the viability of a water supply option is not dependent on its quality, cost and quantity.

The study utilized Chi-square test in testing the null hypothesis formulated in the study. Chi-square is a statistical test commonly used to compare observed data with data expected to be obtained according to a specific hypothesis. The chi-square test is always a test for the null hypothesis, which states that there is no significant difference between the expected and observed result. Testing of the null hypotheses in this study was based on the fact that if the calculated Chi-square is more than the critical (tabulated) Chi-square value at a probability level of 95% or a significance level p value = 0.05, then it would not be possible to accept the null hypothesis.

4.7.1 Relationship between quality of water and accessibility of a water supply

The analysis looked at the relationship between quality of water and viability of a water supply option. The following illustrates the statistical relationship between them.

$Ho_{1.}$ There is no statistically significant influence of quality of water on the viability of a water supply option in Kisauni area of Mombasa County.

Chi-Square Tests

	Value	Df	Asymp.Sig. (2-sided)
Pearson Chi-Square	38.322	9	.001
Likelihood Ratio	39.175	9	.000
Linear-by-Linear Association	10.517	1	.001
N of Valid Cases	300		

Table 4.1.8: Chi-Square tests results on relationship between quality of water and accessibility of water supply

The results indicate that the chi-squared test statistic is 38.322 with an associated p of 0.001. In this case, since $p < 0.05$, therefore the null hypothesis is rejected that there is no relationship between quality of water and the accessibility of a water supply option in Kisauni Mombasa and the alternative hypothesis is accepted. Thus, there is a statistically significant relationship between the quality of water and the accessibility of a water supply in Kisauni Mombasa.

4.7.2 Relationship between cost of water and accessibility of a water supply in Kisauni Mombasa

The analysis also explored the relationship between cost of water and viability of a water supply in Kisauni Mombasa.

$Ho_{2.}$ There is no statistically significant influence of cost of water on the accessibility of a water supply in Kisauni Mombasa.

Chi-Square Tests

	Value	df	Asymp. Sig.(2-sided)
Pearson Chi-Square	23.883	6	.001
Likelihood Ratio	27.973	6	.000
Linear-by-Linear Association	.415	1	.519
N of Valid Cases	300		

Table 4.1.9: Chi-square tests on relationship between cost of water and accessibility of water supply in Kisauni Mombasa

The chi-squared test statistic is 23.883 with an associated *p* of 0.001. In this case, since associated *p* is <0.05 (table 4.1.9), the null hypothesis is rejected and a conclusion is made that cost of water contributes towards accessibility of a water supply option in Kisauni Mombasa. Thus, there is a statistically significant relationship between cost of water and accessibility of a water supply option in Kisauni Mombasa**.**

4.7.3 Relationship between quantity of water and accessibility of water supply in Kisauni area of Mombasa County.

The analysis further looked at the relationship between quantity of water and accessibility of water supply in Kisauni Mombasa. The following illustrates the statistical relationship between the two variables.

Ho_3. There is no statistically significant relationship between quantity of water and the viability of a water supply option in Kisauni Mombasa.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	20.773	6	.003
Likelihood Ratio	25.113	6	.000
Linear-by-Linear Association	.421	1	.587
N of Valid Cases	300		

Table 4.2.1: Chi-square tests relationship between quantity of water and accessibility of water supply in Kisauni Mombasa

Table 4.2.1 shows that the chi-squared test statistic is 20.773 with an associated p of 0.03. In this case, since associated p is <0.05, therefore the null hypothesis is rejected and a conclusion is made that quantity of water is related to the viability of a water supply option in Kisauni Mombasa. Therefore, there is a statistically significant relationship between quantity of water and the accessibility of water supply in Kisauni Mombasa.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter presents summary of findings, conclusion and recommendations of the study in line with the objectives.

5.1 Summary of the Findings

The study established that tap water was very costly and majority of the residents could not access it. The high cost of water reduced the accessibility of water. However, tap water was of good quality and at the same time of insufficient quantity. The groundwater was relatively less costly and the quantity accessible was satisfactory but it was found to be of very poor quality.

From the findings, it was also established that the quantity of water accessible to the residents in Kisauni area was determined by the cost of water. The increase in cost of water prohibited availability of more quantity of water as to purchase a large quantity required the respondents to pay a higher cost. This depicts that the cost of water influenced the accessibility of water supply as it determined the quantity of water available for the area residents.

The study further established that most of the respondents had access to water of poor quality. The tap water across Kisauni Division of Mombasa is characterized by low levels of access as well as poor service quality in terms of intermittent supply. The tap water is physically, chemically and biologically fit for human consumption. It was found to be fit for drinking and for domestic uses since all the analyzed parameters fall far below the WHO specified standards. However, the cost of accessing it was far too high for the residents.

The researcher further revealed that the harmful bacteria in the tap water were completely absent as required by WHO drinking water standards. This depicts that the tap water in

Kisauni Mombasa County was fit for drinking purposes and other domestic purposes without any further treatment.

On the other hand, based on the physical and chemical parameters, the ground water was fairly good for human consumption. However the two chemical parameters of conductivity and salinity were far above the specified WHO standards. Conductivity measuring up to 2180 µs/cm and salinity measuring up to 478.5 mg/l against WHO maximum of 2000 µs/cm and 250 mg/l respectively. Bacteriologically, the general coliform measured as high as 2100 MPN/100ml and1200 MPN/100ml for E. coli. This meant that the water was heavily contaminated. Out of the six wells sampled none produced water that's fit for human consumption. This water could therefore not be used for drinking purposes without further treatment. Without further treatment the water could only be used for limited domestic uses like washing clothes. The poor quality of ground water therefore reduced the accessibility option of water from ground water.

The treatment method that is suitable for Kisauni area and therefore the larger Mombasa County is the one that could reduce salinity to acceptable levels and at the same time killing the bacteria present in groundwater hence improving groundwater quality at the same time increasing water supply to solve the shortage of tap water supply without compromising the cost too much. Desalination using solar still is one such a method.

The researcher established that the accessibility of a water supply source was based on availability, affordability, water quality and knowledge of a water source respectively.
From the chi-test, the researcher established there is a statistically significant relationship between the quantity, quality and cost of water and the accessibility of water supply in Kisauni Mombasa.

5.2 Conclusions

The study concludes that although tap water would have been the preferred water supply option to Kisauni residents and the larger Mombasa County because of its good quality its accessibility is limited due to its intermittent supply hence the residents cannot access the quantity they desire and its cost is also unaffordable. This makes tap water an inaccessible water supply option for Kisauni residents.

Groundwater on the other hand is easily accessible in satisfactory quantity and cost but its accessibility is also limited due to its poor quality (chemically and biologically). This means the water cannot be used without further treatment.

The most accessible water supply for Kisauni residents is to adopt the water desalination approach especially the one presented in this study (solar still desalination) to improve the quality (both chemically and biologically) of the already available groundwater within a reasonable initial and maintenance cost because solar energy is free and abundant all year round especially during the dry season when all other sources of water are unavailable.

5.3 Recommendations

5.3.1 To the Government and Other relevant authorities

The government should look more into the underutilized available water resources like groundwater and seawater because surface freshwater is almost being depleted. It should set money aside in its budget for initial and maintenance cost to help the resident access good quality water at reasonable quantity and cost.

The government should source for more information and expertise from the countries that have succeeded in solar desalination.

Conduct awareness on the importance of improving the quality of water at the point of use to reduce the burden of waterborne diseases hence reduce the health budget and increase the productivity of its citizens.

5.3.2 To the Local Community and Other Water Users

The local community should learn to take initiative to improve their own water supply in terms of Quality, Quantity and Cost by adopting this new simple purification method presented in this study instead of relying on water from neighboring counties, while they are in a county that there is water everywhere but not a drop to drink.

Communities should form groups in terms of households to combine efforts and resources to construct and maintain a solar still that will serve that particular group.

The resultant salt (brine) can be used a raw material for salt manufacturing for domestic use by the households or sell to the salt manufacturing companies at the coast to enhance the community livelihoods.

5.4 Areas for Further Research

More research should be conducted on how to improve the capacity and productivity of the solar stills especially by finding out construction material that can resist solar radiation for the longest time possible.

Water quality analysis of the desalinated water should be carried out and the possible way of blending it to make fit for human consumption because it is completely demineralized

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APPENDICES

APPENDIX I: QUESTIONNAIRE

Instructions

This questionnaire is for the purpose of the academic research only and the information you give will be treated utmost confidentially. The study is on the **factors affecting accessibility of water supply: a case study of Kisauni Mombasa.** Please answer all the questions provided as honestly as possible, to the best of your knowledge.

Section A: Demographic Information (Tick (√) the appropriate option (bracket)

1. What is the household size of your family?

1 – 5 members [ ] 6 – 10 members [ ] 11 – 15 members [ ] over 15 members [ ]

2. What is your household water consumption per day?

1–50 litres [ ] 51–100 litres [ ] 101–150 litres [ ] 151–200 litres [ ] 201 litres and above [ ]

3. Indicate the sources of water that your household has access to**?**

Tap water [ ] Groundwater [ ] both [ ]

Section B: Factors affecting accessibiliy of water supply options: a case study of Kisauni Mombasa.

The effect of cost in accessing water

4. Kindly rate the how cost of water that influences accessibility of water from different water sources using a tick on each water source?

	Tap water	Groundwater
Rating		
Very high		
High		
Fair		
Low		

Where Low = < Kshs 100 per month

Fair = Kshs 100 - Kshs 250 per month

High = Kshs 250 – Kshs 500 per month

Very = > Kshs 500

5. How would you rate the quality of water that your family has access to?

Very high quality [ ] High quality [ ] Poor quality [ ] Low quality [ ]

6. Kindly indicate the sources of water that produces good quality of water in the area.

a) **Tap water**

Very high [ ] High [ ] Low [ ]

b) **Groundwater**

Very high [ ] High [ ] Low [ ]

7. Kindly rate the accessibility of water from different sources in Kisauni using Use a scale of 1-5 where 1= Not at all, 2-low extent, 3-moderate extent, 4-great extent and 5= Very great extent?

	1	2	3	4	5
Tap water					
Groundwater					

8. Kindly indicate the extent to which the quantity of water is adequate for household use? Very great extent [ ] Great extent [ ] Moderate extent [ ] Low extent [ ]

9. What are the factors that affect the viability of a water source?

	Yes	No
Affordability		
Availability		
Quality		
Knowledge of the source		
Management		

Thank you for your time and participation

APPENDIX II: TAP WATER ANALYSIS REPORT KISAUNI SOKONI

SAMPLE No: 436/2012 **DATE SAMPLED:** 07/09/2012 **DATE SUBMITTED:** 07/09/2012

SOURCE: Tap 1 Kisauni Sokoni **SUBMITTED BY:** Miss. Everlyne Mwamburi

PURPOSE OF SAMPLING: Research

No.	**PARAMETERS**	UNITS	**RESULTS**	**WHO STANDARDS**
1.	pH	pH Scale	7.58	6.5 – 9.0
2.	Turbidity	NTU	1	Max 25
3.	Conductivity	µs/cm	0.007	Max 2000
4.	Total Hardness	mg/1	121	Max 500
5.	Chloride	mg/l	1	Max 600
6.	Total Alkalinity	mg/l	39	Max 500
7.	Magnesium	mg/l	1.4	Max 150
8.	Calcium	mg/l	3.4	Max 250
9.	Total Dissolved Solids	mg/l	65	Max 2000
10.	Salinity	Mgl	110	Max 250
11.	General Coliform Counts	MPN/100ml	Nil	Nil
12.	E.Coliform Counts	MPN/100ml	Nil	Nil
13.	Colour	Hazen	Clear	Max 15

J. Nguru

WATER QUALITY OFFICER

APPENDIX III: TAP WATER ANALYSIS REPORT MKOMANI

SAMPLE No: **437/2012** DATE SAMPLED: **07/09/2012** DATE SUBMITTED: **07/09/2012**

SOURCE: Tap 2 Kisauni ***S*UBMITTED BY:** Miss. Everlyne Mwamburi

PURPOSE OF SAMPLING: Research

No.	**PARAMETERS**	UNITS	**RESULTS**	**WHO STANDARDS**
1.	pH	pH Scale	6.9	6.5 – 9.0
2.	Turbidity	NTU	1	Max 25
3.	Conductivity	µs/cm	0.03	Max 2000
4.	Total Hardness	mg/1	70	Max 500
5.	Chloride	mg/l	14.6	Max 600
6.	Total Alkalinity	mg/l	72	Max 500
7.	Magnesium	mg/l	1.8	Max 150
8.	Calcium	mg/l	13.4	Max 250
9.	Total Dissolved Solids	mg/l	109	Max 2000
10.	Salinity	Mgl	98	Max 250
11.	General Coliform Counts	MPN/100ml	Nil	Nil
12.	E.Coliform Counts	MPN/100ml	Nil	Nil
13.	Colour	Hazen	Clear	Max 15

J. Nguru

WATER QUALITY OFFICER

APPENDIX IV: TAP WATER ANALYSIS REPORT MTOPANGA

SAMPLE No: 438/2012 **DATE SAMPLED:** 07/09/2012 **DATE SUBMITTED:** 07/09/2012

SOURCE: Tap 3 Kisauni **SUBMITTED BY:** Miss. Everlyne Mwamburi

PURPOSE OF SAMPLING: Research

No.	**PARAMETERS**	UNITS	**RESULTS**	**WHO STANDARDS**
1.	pH	pH Scale	7.1	6.5 – 9.0
2.	Turbidity	NTU	1	Max 25
3.	Conductivity	µs/cm	0.05	Max 2000
4.	Total Hardness	mg/1	90	Max 500
5.	Chloride	mg/l	31.9	Max 600
6.	Total Alkalinity	mg/l	78	Max 500
7.	Magnesium	mg/l	0.7	Max 150
8.	Calcium	mg/l	21.7	Max 250
9.	Total Dissolved Solids	mg/l	210	Max 2000
10.	Salinity	Mgl	90	Max 250
11.	General Coliform Counts	MPN/100ml	Nil	Nil
12.	E.Coliform Counts	MPN/100ml	Nil	Nil
13.	Colour	Hazen	Clear	Max 15

J. Nguru

<u>WATER QUALITY OFFICER</u>

APPENDIX V: GROUNDWATER ANALYSIS REPORT SOKONI

SAMPLE No: 439/2012 **DATE SAMPLED:** 07/09/2012 **DATE SUBMITTED: 07**/09/2012

SOURCE: Well 1 Kisauni **SUBMITTED BY:** Miss. Everlyne Mwamburi

PURPOSE OF SAMPLING: Research

No.	**PARAMETERS**	UNITS	**RESULTS**	**WHO STANDARDS**
1.	pH	pH Scale	6.9	6.5 – 9.0
2.	Turbidity	NTU	0.73	Max 25
3.	Conductivity	µs/cm	1830	Max 2000
4.	Total Hardness	mg/1	300	Max 500
5.	Chloride	mg/l	184	Max 600
6.	Total Alkalinity	mg/l	290	Max 500
7.	Magnesium	mg/l	2.44	Max 150
8.	Calcium	mg/l	81	Max 250
9.	Total Dissolved Solids	mg/l	1021	Max 2000
10.	Salinity	Mgl	361.7	Max 250
11.	General Coliform Counts	MPN/100ml	2100	Nil
12.	E.Coliform Counts	MPN/100ml	760	Nil
13.	Colour	Hazen	2.5	Max 15

J. Nguru

WATER QUALITY OFFICER

APPENDIX VI: GROUNDWATER ANALYSIS REPORT MKOMANI

SAMPLE No: 440/2012 **DATE SAMPLED:** 07/09/2012 **DATE SUBMITTED:** 07/09/2012

SOURCE: Well 2 Kisauni **SUBMITTED BY:** Miss. Everlyne Mwamburi

PURPOSE OF SAMPLING: Research

No.	PARAMETERS	UNITS	RESULTS	WHO STANDARDS
1.	pH	pH Scale	6.8	6.5 – 9.0
2.	Turbidity	NTU	1.79	Max 25
3.	Conductivity	µs/cm	2160	Max 2000
4.	Total Hardness	mg/1	320	Max 500
5.	Chloride	mg/l	216	Max 600
6.	Total Alkalinity	mg/l	325	Max 500
7.	Magnesium	mg/l	20.23	Max 150
8.	Calcium	mg/l	28.4	Max 250
9.	Total Dissolved Solids	mg/l	1100	Max 2000
10.	Salinity	Mgl	478.5	Max 250
11.	General Coliform Counts	MPN/100ml	1600	Nil
12.	E.Coliform Counts	MPN/100ml	1000	Nil
13.	Colour	Hazen	2.5	Max 15

J. Nguru

WATER QUALITY OFFICER

APPENDIX VII: GROUNDWATER ANALYSIS REPORT MTOPANGA

SAMPLE No: 441/2012 **DATE SAMPLED:** 07/09/*2012* **DATE SUBMITTED:** 07/09/2012

SOURCE: Well 3 Kisauni **SUBMITTED BY:** Miss. Everlyne Mwamburi

PURPOSE OF SAMPLING: Research

No.	**PARAMETERS**	UNITS	**RESULTS**	**WHO STANDARDS**
1.	pH	pH Scale	7.2	6.5 – 9.0
2.	Turbidity	NTU	1.70	Max 25
3.	Conductivity	µs/cm	2020	Max 2000
4.	Total Hardness	mg/1	422	Max 500
5.	Chloride	mg/l	436	Max 600
6.	Total Alkalinity	mg/l	269	Max 500
7.	Magnesium	mg/l	10.56	Max 150
8.	Calcium	mg/l	49.41	Max 250
9.	Total Dissolved Solids	mg/l	850	Max 2000
10.	Salinity	Mgl	378	Max 250
11.	General Coliform Counts	MPN/100ml	1200	Nil
12.	E.Coliform Counts	MPN/100ml	1200	Nil
13.	Colour	Hazen	2.5	Max 15

J. Nguru

WATER QUALITY OFFICER

APPENDIX VIII: GROUNDWATER ANALYSIS REPORT BAMBURI

SAMPLE No: 442/2012 **DATE SAMPLED:** 07/09/2012 **DATE SUBMITTED:** 07/09/2012

SOURCE: Well 4 Kisauni **SUBMITTED BY:** Miss. Everlyne Mwamburi

PURPOSE OF SAMPLING: Research

No.	PARAMETERS	UNITS	RESULTS	WHO STANDARDS
1.	pH	pH Scale	6.9	6.5 – 9.0
2.	Turbidity	NTU	1.27	Max 25
3.	Conductivity	µs/cm	2180	Max 2000
4.	Total Hardness	mg/1	350	Max 500
5.	Chloride	mg/l	158	Max 600
6.	Total Alkalinity	mg/l	378	Max 500
7.	Magnesium	mg/l	17.48	Max 150
8.	Calcium	mg/l	48.17	Max 250
9.	Total Dissolved Solids	mg/l	1050	Max 2000
10.	Salinity	Mgl	270	Max 250
11.	General Coliform Counts	MPN/100ml	1800	Nil
12.	E.Coliform Counts	MPN/100ml	600	Nil
13.	Colour	Hazen	2.5	Max 15

J. Nguru

WATER QUALITY OFFICER

APPENDIX IX: GROUNDWATER ANALYSIS REPORT KIEMBENI

SAMPLE No: 443/2012 **DATE SAMPLED: 07**/09/2012 **DATE SUBMITTED:** 07/09/2012

SOURCE: Well 5 Kisauni ***S*UBMITTED BY:** Miss. Everlyne Mwamburi

PURPOSE OF SAMPLING: Research

No.	PARAMETERS	UNITS	RESULTS	WHO STANDARDS
1.	pH	pH Scale	7.1	6.5 – 9.0
2.	Turbidity	NTU	1.97	Max 25
3.	Conductivity	µs/cm	2060	Max 2000
4.	Total Hardness	mg/1	390	Max 500
5.	Chloride	mg/l	217	Max 600
6.	Total Alkalinity	mg/l	350	Max 500
7.	Magnesium	mg/l	9.74	Max 150
8.	Calcium	mg/l	74.9	Max 250
9.	Total Dissolved Solids	mg/l	990	Max 2000
10.	Salinity	Mgl	315.9	Max 250
11.	General Coliform Counts	MPN/100ml	1000	<10
12.	E.Coliform Counts	MPN/100ml	800	Nil
13.	Colour	Hazen	2.5	Max 15

J. Nguru

WATER QUALITY OFFICER

APPENDIX X: GROUNDWATER ANALYSIS REPORT SHIMO PRISON

SAMPLE No: 444/2012 **DATE SAMPLED:** 07/09/2012 **DATE SUBMITTED:** 07/09/2012

SOURCE: Well 6 Kisauni **SUBMITTED BY:** Miss. Everlyne Mwamburi

PURPOSE OF SAMPLING: Research

No.	**PARAMETERS**	UNITS	**RESULTS**	**WHO STANDARDS**
1.	pH	pH Scale	7.2	6.5 – 9.0
2.	Turbidity	NTU	1.05	Max 25
3.	Conductivity	µs/cm	1824	Max 2000
4.	Total Hardness	mg/1	370	Max 500
5.	Chloride	mg/l	178	Max 600
6.	Total Alkalinity	mg/l	354	Max 500
7.	Magnesium	mg/l	12.2	Max 150
8.	Calcium	mg/l	133.65	Max 250
9.	Total Dissolved Solids	mg/l	815	Max 2000
10.	Salinity	Mgl	297.7	Max 250
11.	General Coliform Counts	MPN/100ml	1440	Nil
12.	E.Coliform Counts	MPN/100ml	480	Nil
13.	Colour	Hazen	2.5	Max 15

J. Nguru

<u>WATER QUALITY OFFICER</u>