ENHANCING HOUSEHOLD WATER USE EFFICIENCY AND DOMESTIC RAINWATER HARVESTING POTENTIAL IN NAIROBI COUNTY

By

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DECLARATION

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ABSTRACT

Water is a finite resource without which life would be void. The world is grappling with the issue of clean water provision in the phase of rapid population growth and pollution of freshwater bodies due to human activities such as industrial growth. Inequitable access to water is more persistent in developing countries, more so, in Sub-Saharan Africa. Kenya as a country lacks mechanisms that will cushion it from the imminent scarcity that is recorded in the Kenya Vision 2030; amongst other documents. Nairobi being the most populated county in the country serves as a good reference point for the study on the efficiency of use of water at the household level. In this study, efficiency of use has been broken down into two components namely: the general utilization of water and water supply diversification (this includes rainwater harvesting, use of proper plumbing fittings, and gray water re-use). This study reports the efficiency of use as investigated at the household level and the possibility of diversifying supply, together with the costs and opportunities available in diversification.

Both primary and secondary data were used in the actualization of this research. Primary data were collected through the use of questionnaires which were administered to respondents from two income clusters, that is, low and middle income households. The questionnaires were analyzed using SPSS and Microsoft Excel. Similarly, secondary data were collected from relevant organizations and analyzed using Microsoft Excel. The information obtained from the analysis has been presented through descriptive statistics incorporating tables and figures. The findings indicate that efficient water use is lacking. In addition, a lot of water from rain is being lost since there is no adequate infrastructure put up by developers to tap this water; this is made worse by the type of house tenure available to most residents in the city. The cost of water is also misleading to consumers since it is heavily subsidized. The cost of diversification to gray water and rainwater is very high.

It is recommended that consumers need to be sensitized on efficient water utilization; moreover, there is need for research to further knowledge into better household water resource utilization. Rainwater should be harvested or fed into the water table. Finally, there is need for water prices to be harmonized in order to reflect the real cost of water.

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LIST OF ACRONYMS

ARR	Average Rate of Return
AWSB	Athi Water Services Board
BAU	Business as Usual
CBA	Cost Benefit Analysis
DRWH	Domestic Rainwater Harvesting
EU	European Union
GOK	Government of Kenya
HETs	High Efficiency Toilets
IRR	Internal Rate of Return
KNBS	Kenya National Bureau of Statistics
Kshs.	Kenya Shillings (Kshs. 88= 1USD)
MIRR	Modified Internal Rate of Return
NCWSC	Nairobi City Water and Sewerage Company
NPV	Net Present Value
UfW	Un-accounted for Water
UN	United Nations
UNEP	United Nations Environment Programme
USD	U.S Dollar
WASREB	Water Services Regulatory Board
WTA	Willingness to Accept
WTP	Willingness to Pay

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CHAPTER 1: INTRODUCTION

1.1 Background Information

Nairobi's growth as an urban centre started in the year 1899 when it became a railway transport centre for the Kenya Uganda Railways (Mitullah, 2002). By 1907, it had been elevated to become Kenya's capital centre. Due to the increase in population and economic activity, it was declared a city in 1950 (ibid). Nairobi's administrative boundaries were expanded over time, this was concluded in 1963. In the year 2010, upon the promulgation of Kenya's new constitution, Nairobi City became a County (Kenya Constitution, 2010). Plans by the government to expand the City have been ongoing, with the spatial boundaries being adjusted to include three more counties: Kajiado, Kiambu, and Machakos; to form the greater Nairobi Metropolitan Region (GOK, 2011).

With an area of 695km^2, translating to only 0.1% of Kenya's total land area, Nairobi County plays host to the largest population in the country(8%) when compared with the other counties (Kenya Bureau of Statistics, 2010). With this huge population and very minimal growth in water supply and sanitation infrastructure, Nairobi faces a myriad of challenges in provision of water and sanitation services with most informal settlements in the County totally locked out of the supply grid (Athi Water Services Board, 2012). Athi Water Service Board (AWSB) is one of the eight water services boards in Kenya. It operates directly under Water Services Regulatory Board (WASREB) which was instituted by the now defunct Ministry of Water and Irrigation to control the management of water services in the country. AWSB has vested the mandate of water and sewerage service provision in Nairobi County to Nairobi City Water and Sewerage Company (NCWSC) as a water service provider (Water Act, 2002; Athi Water Services Board, 2012).

The water supplied to Nairobi is sourced from the Aberdares, Ranges. This is done through four dams that were constructed between 1900 and 1994. These are: Kikuyu Springs, Ruiru Dam, Sasumua Dam, and Thika Dam. Together, they have a daily supply of 509, 900m^3 (Athi Water Services Board, 2012). The daily household water supply is distributed as shown in Figure 1.

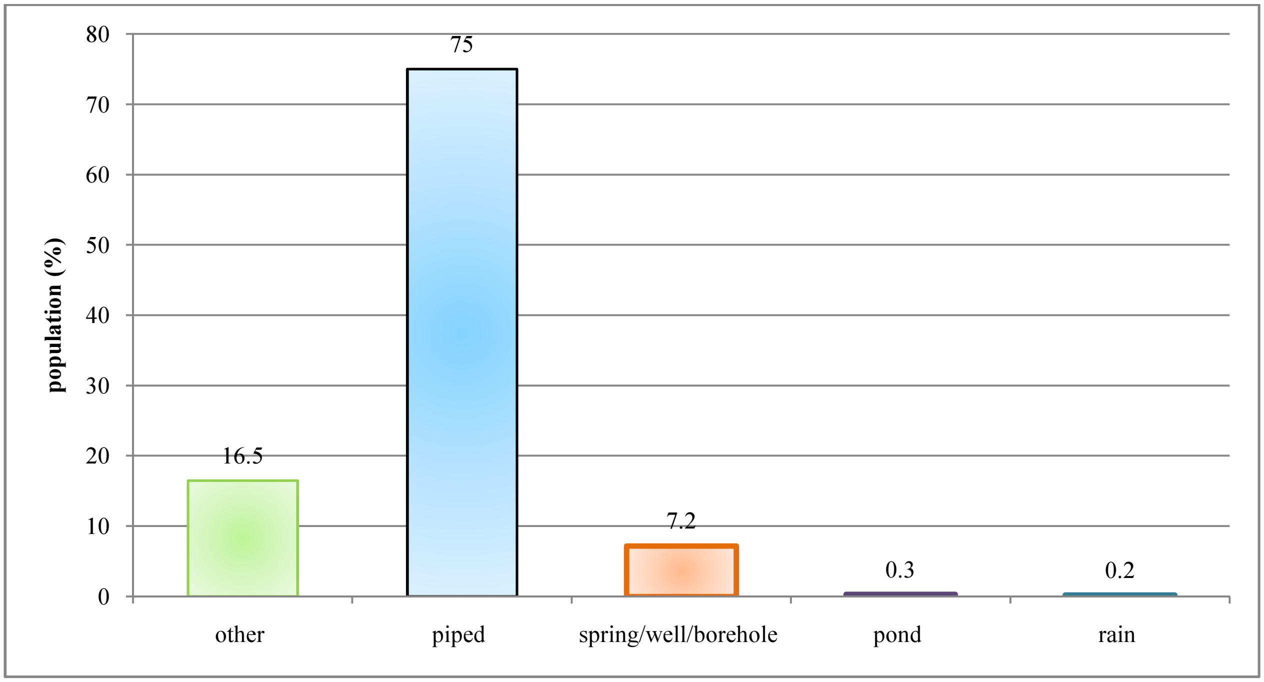

Figure 1: Nairobi's daily household water supply (Source: KNBS, 2010)

As the County's population grows, water consumption is rising as well. By the year 2030, the County's water demand is projected to range between 954,415m^3/d and 1,083,572m^3/d. These figures double the current supply of 509, 900m^3/d (Athi Water Services Board, 2012).

Like many other countries, Kenya relies on its building code to guide new and renovation constructions by setting minimum standards of compliance. The County does not have a policy on water currently. Water use efficiency and rainwater harvesting are not factored in to the Kenyan code (Billi et al, 2007; GOK, 1968). Majority (75%) of Nairobi households, rely on piped water (Kenya National Bureau of Statistics, 2010). The use of underground water is also growing steadily, despite the fact that it is a disputed water source that could end up exposing users and habitants to catastrophic risks (Foster and Tuinhof, 2005). If Nairobi is to meet its growing water demand (Kenya Vision 2030, 2007), then the current water sources have to be diversified and better utilized (Lloyd *et al*. 2012).

1.2 Statement of the Research Problem

It is a known fact that cities are on the fast-lane to scarce freshwater resources in future due to industrialization, population growth, and climate change. Urban households have a huge impact on the existing natural water balance that needs efficient control in order to reduce their environmental footprint (Shuetze and Fandino, 2013). City governments such as Nairobi County Council have the opportunity of diversifying urban water supply. This can be achieved through three major options namely: 1) domestic rainwater harvesting (DRWH), 2) waste water re-use and3) thoughtful and efficient use of the existing dwindling resources. Options available for exploration include: a) the use of water efficient plumbing installations in buildings, 2) proper and regular maintenance of these fittings, and 3) efficient and technologically sound consumption monitoring. In addition to this, monthly consumption quotas can be established to ensure that water consumption per household does not exceed a certain limit. It is against this backdrop that this study was conducted in order to evaluate the possibility of 1) diversifying domestic water supply through harvesting rainwater and re-using domestic waste water, 2) implementing efficiency of water use at the household level by using low consumption plumbing fittings in both old and new buildings, and 3) the financial implication of diversifying supply and enhancing efficiency of use of the existing supply.

1.3 Research Questions

Given the foregoing discussion, this study was guided by the following main question:

- How efficient are domestic rainwater harvesting and water use amongst Nairobi households and what are the costs and benefits of improving them?

This question was broken into three constituent parts of:

i. How much water was supplied to each household in Nairobi County, and how efficiently was this water utilized?

ii. How much roof catchment rainwater was available for harvest to each household annually, how much of it was actually harvested, and how was it utilized?

iii. What were the costs and benefits of improving the existing efficiency levels in household water use and domestic rainwater harvesting against retaining the existing situation?

1.4 Purpose and Objectives of the Study

The purpose of this study was to investigate the existing household water use efficiency, examine the potential for domestic rainwater harvesting, and compare the costs and benefits of improving the existing efficiency levels and increasing the usage of roof harvested rainwater. This was operationalized into three specific objectives namely:

i. To assess the existing water use efficiency levels amongst Nairobi households. This included assessing the types plumbing installations in the houses and the level of their maintenance, as well as examining waste water re-use levels in the households.

ii. To examine the existing level of domestic rainwater harvesting and the available opportunities for improvement.

iii. To compare the costs and benefits of maintaining the status quo in objectives 1 and 2 as opposed to improvement.

1.5 Justification of the Study

As Nairobi's population grows, there are emerging challenges associated with this growth. Solutions that worked a few years back are no longer tenable, in the current water supply system. Burst sewer pipes that threaten the safety of life in the city are a common sight. In addition to this, the rainy seasons are often characterized by poor drainage that sometimes results in flooding. This is evidence that the water supply systems have weakened over time due to pressure and overload from the growing population. It was deemed critical that this study be undertaken, so as to explore the possibility, costs and benefits of having an enhanced and diversified water supply system at the house hold level in Nairobi.

It is hoped that the information generated from this study will be useful to many stakeholders. These include: water service providers who will be better informed on other opportunities available to them in their quest to secure household water sustainability in the city. Housing developers and consumers will benefit from this study in that, through rainwater harvesting, property in water problem areas stands to attract more clients and could result in a higher mark-up for the developers.

Consumers are likely to spend less on water through better harvesting, storage, and utilization techniques. They will also have back-up supply during drought or supply interruptions such as pipe bursts. Through the implementation of the findings in this study, slum dwellers stand to have improved access to clean water at a lower cost. Non-governmental organisations, especially those working on water service provision in slum areas will be able to use the information obtained from this study to improve their work.

Policy makers such as members of the National Parliament and the Nairobi City County assembly will be better informed as they draft new policies through which, building consultants will have a greater chance of designing water efficient structures, as well as give advice to their clients. The new Nairobi water master plan is funded by the World Bank and the French Development Agency (AWSB, 2012); these donors have the chance to give informed directives in the implementation of the said master plan through this study.

1.6 Limitations of the Study

This study faced various challenges that dictated the final output. These were mainly time, and monetary constraints as well as security concerns. The study was conducted when the country was grappling with numerous security challenges a situation that made it difficult to access the initial selected study area, as a result of which the upper income group was excluded from the research.

1.7 Organization of the Thesis

The thesis is organized in five chapters. First is chapter 1 which gives an introduction to the study, including the statement of the research problem. This is followed by chapter 2, which looks at and records the literature that has been referred to and used to shape this study. Chapter 3 deals with the methodological review, and orientation that was used to collect data. Chapter 4 gives a detailed analysis of the data collected. The data includes both primary and secondary data. Finally, chapter 5 concludes the research by giving recommendations and possible policy options gleaned from the research.

CHAPTER 2: LITERATURE REVIEW

2.0 Overview of Chapter

This chapter examines various studies that have been carried out in relation to water use efficiency, domestic rainwater harvesting, and cost benefit analysis. In addition, it looks at the methodology used by different researchers that will inform the design of research methodology in the subsequent chapter. The main aim of this chapter is to identify knowledge gaps in water use efficiency and domestic rainwater harvesting in Kenya and inform the design of the field survey.

2.1 Water Use Efficiency

Water use efficiency comprises any deliberate measure to reduce the amount of water used per unit of a given activity with the aim of maintaining or improving water quality (Billi et al, 2007). This is achieved when the market cost of water is fully valued to reflect the social costs incurred during supply, thereby acting as an incentive to efficiency of use (ibid). Water use efficiency can be broken down into various components namely: a) physical or absolute efficiency, b) environmental efficiency, c) economic efficiency, d)social efficiency, e)technological efficiency, and f) institutional efficiency (ibid).

Water use efficiency can only be obtained through policies that encourage conservation hence acting as mitigative measures to the ever growing pressures on the resource (Madebwe, and Madebwe, 2011). The policies should target demand management thereby encouraging thoughtful use of the diminishing resource. Use efficiency is a core component in water demand management. In Gweru, Zimbabwe, this has been achieved through additional charges for consumption beyond preset monthly quotas. Each household is allocated $20m^3$ of water per month at a cost of USD 0.14 per cubic meter, any additional unit consumed is charged as follows: 21-30m^3 costs USD 0.21, 31-50m^3 is charged USD 0.28, 51-100m^3 is charged USD 0.35, and consumption above 100m^3 is charged USD 0.42 (ibid).

However, different households have varying water demands, due to characteristics such as: income levels, domestic water saving technologies, and use of water for needs such as landscape irrigation. As such, different households respond differently to demand side management policies (Thomas, 1998; Archibald, and Renwick, 1998). In Gweru, income was found to be an indicator of affluence, hence the people in the higher income groups exceeded the allocated quotas by over 55% in the period between 2005 and 2010 (Madebwe, and Madebwe, 2011). This scenario reinforces Archibald's and Renwick's (1998) argument that price policies by themselves are not effective in enhancing water use efficiency and have to be combined with non-price policies such as rationing, subsidies for water efficient technologies, household specific water allocations with penalties for non-compliance, restrictions on uses such as landscape irrigation, and finally, educational campaigns to encourage water conservation (ibid).

In Gweru, the non-price policies that have been adopted in addition to the economic ones discussed earlier include both social and regulatory strategies. The social strategies comprise of: water conservation messages on bills and at bill payment points (Madebwe, and Madebwe, 2011) as well as educational campaigns. Regulatory strategies include: permanent water restrictions, reduced flows through mechanical devices, and restrictions on water use. Perhaps the combination of both price and non-price strategies in Gweru is potentially what has led to higher water use efficiency.

Between 1985 and 1990, the State of California in U.S.A experienced severe drought that led to significant reduction in the levels of water available to the households in the State, which was declared a disaster (Archibald, and Renwick, 1998). The strategies that were adopted in response to this crisis included: rebates on low flow toilets and shower heads, banning certain water uses such as irrigation, block pricing, and water allocation based on historical household use patterns with stiff penalties for non-compliance (ibid).

Various other methods that could encourage efficient use of water have been explored in different parts of the world. One of these is retrofitting[1].This is a strategy best suited to older buildings. In addition, the importance of carrying out water audits[2] in buildings from time to time cannot be overlooked. Consistent water auditing and monitoring plays a crucial role in averting wastage of water (ibid).

Due to technological advancement, housing developers now have a wider array of plumbing fittings to choose from during construction. Choices made for plumbing should therefore be technologically fit so as to aid in water use efficiency. Such technologies could include: dual flush, ultra low flush, or high efficiency toilets (HETs) which consume less water. Similarly, one could use low flow shower heads, and aerated water faucets in the wash basins and kitchen sinks. Additionally, maintenance of the plumbing fittings is essential in averting water loss through leakages or degradation of water quality through contamination by corroded pipes or dirty tanks and cisterns (Hong Kong Waterworks standard requirements handbook on plumbing installation for buildings, 2007).

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[1]To retrofit is to provide with parts, equipment, or devices not in existence or available at the original time of construction(U.S. Department of Housing and Urban Development, 2002)

[2]A water audit is a task that is undertaken to determine how water is being utilized and in what quantities in a given building.

As urban populations grow, cities are shifting their focus to urban farming in order to supplement their food basket; this requires constant watering (Kohi, 2013). Urban farming can either be done vertically on wall facades, or horizontally on roofs and ground (ibid). Introducing low water consumption irrigation systems goes a long way in conserving water. Low density urban settlements consume more water for landscape irrigation and other outdoor uses such as cleaning and filling up swimming pools when compared to high density areas which have minimal open spaces (Archibald, and Renwick, 1998). It is essential that any water efficiency strategy takes this into consideration (ibid).

2.2 Domestic Rainwater Harvesting

Thomas (1998) suggests that domestic water is never really lost through consumption, but rather through dirtying into gray and black water. He therefore proposes two methods of gaining domestic water autonomy as being waste water recycling, and rainwater harvesting. Domestic rainwater harvesting (DRWH) is the interception of water from rain on a surface and subsequent storage for later use (ibid; Texas Water Development Board, 2011). The intercepting surfaces could either be roof systems or ground surfaces. The collected water is stored in tanks, cisterns, and barrels depending on the financial capacity of the harvesters. Rainwater harvesting has long been a major source of water supply for poor people in rural Africa, but has the potential of being enhanced in urban settings as well (Thomas, 1998).

Although rainwater is a free and naturally occurring resource; it faces costs that impede its development. The three key costs required in order to set up a harvesting system being: a) the collection surface, b) guttering, and c) storage. Others could include treatments, filters, water pumps, and system maintenance (ibid).

When proposing a rainwater harvesting system, one should consider factors such as: the type of roofing material, the roof catchment area, and the size of the storage tank for the harvested water (Ministry of Water and Irrigation Practice Manual for Water Supply Services, 2005). As a rule of thumb, the volume of water that can be captured and stored from rain (supply) must equal or exceed the volume of water needed for a given period (demand) (Texas Water Development Board, 2011). According to the Ministry of Water and Irrigation Practice Manual for Water Supply Services, 2005, a runoff coefficient of 0.8 should be assumed for the various roofing materials in use in Kenya which include: clay and concrete roof tiles, corrugated sheets, concreted bitumen, and plastic sheets (Building Code, 1968). The Texas Water Development Board (2011) proposes a runoff coefficient of 0.85. This figure takes care of the water that is lost through overflow and gutter splash outs.

2.3 Cost Benefit Analysis

This is a tool for decision makers, that helps them pick the best choice from competing options of policies and projects. Simply put, it is the monetary or safety valuation of the risk of performing a task compared to the benefits of performing the task. Cost benefit analysis (CBA) is founded on the premise that, the social benefits gained from a policy or a project must exceed the social costs of the same (Pearce et al, 2006). Benefits are the increments in human welfare or utility, while costs are reductions in human wellbeing that result from a project or policy (ibid). In CBA, a project or policy that diminishes or depletes an environmental asset is counted as a cost, while that which enhances an environmental asset is counted as a benefit.

CBA is hinged on the theory that individual preferences are the source of value. These preferences are measured by the individuals' willingness to pay (WTP) for a gain and their willingness to accept (WTA) compensation for a cost. The individual preferences can be aggregated to obtain the social gain or social cost of a given project (Pearce et al, 2006).

CBA follows a number of stages: a) consideration of all the available options or alternatives including the do nothing or business as usual scenario (BAU) and consequently, the determination of standing (the people that are affected by the costs and benefits). The BAU scenario is not necessarily costless because it involves costs incurred in the maintenance and operation of existing infrastructure (EU, 2008; Pearce et al, 2006); b) impacts are assessed; c) impacts and time horizons are calculated; e) money values are attached to the options; d) a discount value is selected; g) account for rising relative valuations; and h) deal with risks and uncertainties.

In the City of Melbourne Australia, alternative water sources were identified and their associated costs and benefits evaluated (Lloyd *et al*. 2012). These included: a) mains water supply, which was found to be cheaper as it required no new infrastructure installation, and was well understood by the users. However, it was found to be vulnerable to effects of drought since it was single sourced, faced threats from population pressure, and did not inspire ecological protection from the would be suppliers and users; b) Roof run- off, was found to relieve pressure off the mains supply, reduced storm water overflows, reduced pollution of water bodies, required minimal treatment, and also provided resilience to climate change. The costs associated with rain water included challenges of having the supply meet the existing demand, supply was found to be prone to environmental fluctuations, and the possibility of harvesting contaminated water in heavily polluted areas was real; and c) waste water recycling encouraged water conservation, reduced environmental pollution, and was in constant supply, but required heavy capital outlays in energy and treatment, it also required extra storage, and alternative plumbing.

2.4 Methodological Review

In the quest for cities to gain domestic water autonomy, studies have been conducted in different parts of the world to help towards this goal. Key to this quest is the proper and effective management of water demand in urban areas which translates to water use efficiency. Demand management can be achieved using socio economic parameters as well as institutional and legal frameworks. It is therefore the prerogative of cities, especially those in developing countries to create models that will encourage water use sustainability in order to cushion themselves from possible future water crises. Additionally, there is need for diversification of water resources which can be achieved through utilization of rainwater, surface, and ground water, as well as waste water re-use. This section examines some of the studies that have been conducted around the globe that informed the design of the study methodology for this research.

2.4.1 Studies in water use efficiency

In the study undertaken in Gweru, Zimbabwe (Madebwe and Madebwe, 2011), the main objective was to analyze the existing water demand management policy and its effectiveness in achieving water use efficiency. From the City Council's household water consumption records, a stratified random sampling procedure was used to obtain a list of respondents from the two income groups considered, these were low income and high income residential areas. Three administrative areas were considered. The timeframe considered for the consumption records of the survey was the year 2005 to 2010. The sample houses had to be owner occupied, with continued occupancy from 2005 to 2010; 86 metered houses satisfied the above selection criteria.

Household water consumption histories were reconstructed from the records obtained from the council. In addition, questionnaires were administered to household heads to determine: education levels of household heads, socio economic status, size of residence, and duration of stay at residence. The dependent variable was the monthly water consumption while the independent variables were the period, level of income, and household head's level of education.

The findings from this study indicated that the less educated people in the community were more sensitive to water use efficiency, majority of whom belonged to the lower income group. The high income groups were more extravagant with water use and were able to pay for the higher premiums that came with consumption above the preset monthly quotas. The consumption of more water in high income residences was considered to be a pointer towards more lavish living that required more water; the water was used in appliances such as washing machines, showers, and dish washers. It was also found that a lot of the water was used in landscape irrigation, in addition to other outdoor uses such as in swimming pools. The conclusion from this study indicated that economic parameters by themselves were not effective in promotion of water use efficiency, and had to be used in combination with other mechanisms.

In 2001, UNEP undertook a survey, to evaluate how to implement its environmental policy within the UN system, to ensure environmental responsiveness through recycling, reusing, and reducing. Four sources of water were identified: Nairobi County Council, two boreholes, rainwater, and recycled water. Water consumption per capita per day was 145 litres. The activity profiling was as follows: a) sanitation (toilets and urinals); b) catering (cafeteria and restaurant), c) cleaning (offices, official vehicles and showers for staff), and d) landscaping of the UN compound (irrigation of plants and circulation ponds for rearing fish).

Data were collected through: a) direct observation; b) direct measurements which included physical counting of toilets, taps, urinals, and showers and taking actual measurement of the amount of water used in a single flush (with at least one toilet being sampled in each block); c) consultation with the contractors; and d)review of data from previous publications.

From the data collected, the findings were as follows: toilets consumed the bulk of the water at 30%, followed by urinals at 28%, landscaping consumed 8%. Cleaning offices consumed 1,600 litres per week. Other uses included cleaning cars and water for drinking by staff. Waste water was recycled through natural oxidation and used in landscape irrigation.

The recommendations from this study were as follows: a) use of appropriate technology to be achieved through use of high efficiency plumbing devices; b) educating the staff on water conservation; c) diversification of water resources through increased rainwater harvesting and recycling; d) embracing xeriscaping[3] and ensuring plants are watered at appropriate times.

It is possible for global cities to reduce their domestic potable water uptake by up to 50% through diversifying their supply to include other water sources of secondary quality such as rainwater and wastewater (Shuetze and Fandino, 2013). The authors argue that the use of Environmentally Sound Technologies (ESTs) can further be used to reduce household water uptake in urban environments. These ESTs include: toilets, redesigned taps, nozzles with specific flow rates (L/min), and water efficient appliances such as washing machines and dishwashers.

Three main toilet types identified in this paper are: high volume toilets (10L, or more per flush), low volume toilets (1L, 4L, and 6L), and water less or dry toilets. The option for which toilet

[3] Landscaping that is location specific and eliminates the need for supplemental water to the plants through irrigation. An area is planted with plants that are drought resistant and best suited to that location. It is also known as: drought tolerant landscaping, water conserving landscaping, or smart scaping (The Oxford Dictionary, 11th Edition).

type to use is an issue that should be looked at early enough in the construction process, so that the developer makes an informed decision. Around the globe, toilets account for 1/3 of the total water consumed, thus the toilet can be a target area for reducing water consumption, an action that can reduce water uptake by up to 90%. General maintenance is crucial to avoid multiple flushes required for leaking and weak flush toilets that don't get clean on the first flush.

Further, it is argued that, 50% of the water consumed in domestic buildings is through taps and showerheads. The actual consumption through these media is dependent on water pressure, flow rates, purpose, and design. Conventionally, taps and showerheads have flow rates of 14L/min; this can be reduced to 10L/min and below. This paper recommends an average flow of 10L/min as an adequate flow rate.

Other sources such as rainwater and wastewater are viable for supplementing supply. In Flanders, Belgium, it is a requirement by law that houses with roof areas exceeding 70m^2 harvest rainwater. Smaller roof areas should be recommended by law to collect rainwater for groundwater recharge. In countries like Germany, where rainwater use is being encouraged, it has been found that rainwater is safe enough to use for non-consumptive purposes without any treatment whatsoever. This paper recommends separation of gray and black water to effect re-use of gray water.

2.4.2 Studies on domestic rainwater harvesting

India, like many other countries is facing water security problems due to population growth, pollution of surface water, and receding groundwater levels (Kumar, 2004). It is in response to this that cities such as Delhi and Chennai made it mandatory for all residences to have a rainwater harvesting system in place (ibid). The major factors considered in proposing the roof harvesting systems were: hydrological opportunities, and roof area. Analysis of the hydrological opportunities in the areas of study included studying rainfall characteristics such as: magnitude of rainfall, number of rainy days per period, and yearly variations in the amount of rainfall received (ibid).

Generally, houses with large roof surface areas yielded more water, these were typically bungalows. The water harvested had two applications in India: a) as underground water recharge, and b) as domestic water. Assuming a high income household daily water consumption of 500 litres per day, in an area with 1,060mm annual rainfall, using a runoff coefficient of 0.7; a roof area of 300m^2 would provide water for the household for three months. The run-off coefficients used in this study varied as follows: 0.7 for concrete roofs, 0.75 for tiled roofs, 0.8 for asbestos sheets, and 0.9 for galvanized iron sheets.

In a different study, Texas Water Development Board (2011) proposes that for 1 inch (25.4mm) of rain falling on a roof, it produces 0.62 gallons (2.35 litres) of water. However, since some of this water is lost through back splash, the result has to be multiplied by the roof run-off coefficient. Therefore: the annual volume of harvested rain water (gallons) = roof area (square feet) *x* annual rainfall (inches) *x* runoff coefficient *x* 0.62 (gallons/square foot/ inch of rain).

In Kenya, a study was conducted by the government to look into various ways of securing water autonomy in the country. The findings of this study were recorded in the Ministry of Water and Irrigation Practice Manual for Water Supply Services, (2005). Several formulas were recommended by the manual for rainwater harvesting which include: a) how to calculate rainfall yield, b) how to calculate monthly demand for a given number of people, and c) how to calculate minimum tank storage (Page 24).

2.4.3 Studies on cost benefit analysis

It is expected that with a shift to water efficient plumbing fittings and domestic rainwater harvesting, will be a matching capital outlay. Determining the cost and benefits associated with each option will determine the best option at the least cost to the stakeholders. Costs expected from new installations for rainwater harvesting and water use efficiency would include: installation cost, training, and cost of maintenance. Several methods have been used for cost benefit analysis of business investments, these include: a) payback period, which is the time required for a business to break even on an investment. According to Levitan (2010), it can be used to compare the payback period of several projects thereby screening out the least viable ones; b) average rate of return (ARR) which expresses the profits from a given project as a percentage of the initial capital cost; c) net present value (NPV) which is a discounted value that is based on the concept of opportunity cost.; d) internal rate of return (IRR) , this is based on the interest level that a project can withstand, where the NPV should be reduced to zero over the life of the project.

This study will use NPV as the CBA tool. There are four steps in forecasting NPV: a) forecast costs and benefits in each year, b) determine a discount rate, c) calculate NPV, and d) compare the NPV of the various alternatives (Michel, 2001). When forecasting costs and benefits, only monetary costs and benefits should be considered, the forecasts should also be done in the current money values.

2.5 Analytical Framework

2.5.1 Theoretical framework

The economics of water use efficiency is founded on the principle that water prices need to reflect the real social costs incurred in the supply, thereby creating incentives for efficiency of use. Water use efficiency will therefore be achieved when there are measures in place to reduce the amount of water used per unit of a given activity (Billie et al; 2007). Traditionally, water has been a free resource due to the fact that it is naturally occurring, leading to the belief that it is infinite in supply and should be freely accessible; a scenario that has led to the mismanagement of the resource. Water supply is therefore characterized by price distortions between water production and supply (Grimble, 1999).

The cost of water provision is rising, as pollution, climate change, and population growth take their toll on existing water bodies. Economic allocations for purification are growing rapidly as a result of pollution. Additionally, there is growing resource depletion leading to water scarcity. Water has a high unit of value making it difficult to be transported; a huge amount of money is therefore spent on conveyance. Economists have therefore drawn similar conclusions that water should be treated as an economic resource. It is believed that markets and prices can help to ensure sustainable use, minimal waste, optimal allocation, water re-use and recycling, and the development of water efficient technologies (ibid).

Grimble (1999) argues that in order to incentivize conservation, then the cost of water has to reflect its real cost. Maintaining the status quo where water is heavily subsidized will only lead to further depletion, wastage, and inefficient allocation as well as use. In contrast to this, a higher cost of water will encourage efficiency through optimal allocation and investment in water efficient technologies such as high efficiency toilets. This is because human beings are economic beings who respond to incentives and disincentives. Perhaps this would encourage periodic monitoring and water auditing in households as well.

In contrast to this argument, Madebwe and Madebwe (2011) and Archibald and Renwick (1998), have shown that economic parameters by themselves will not be effective deterrents to overuse but have to be used in conjunction with other non-price deterrents such as educating the masses on efficiency of water use.

2.5.2 Conceptual framework

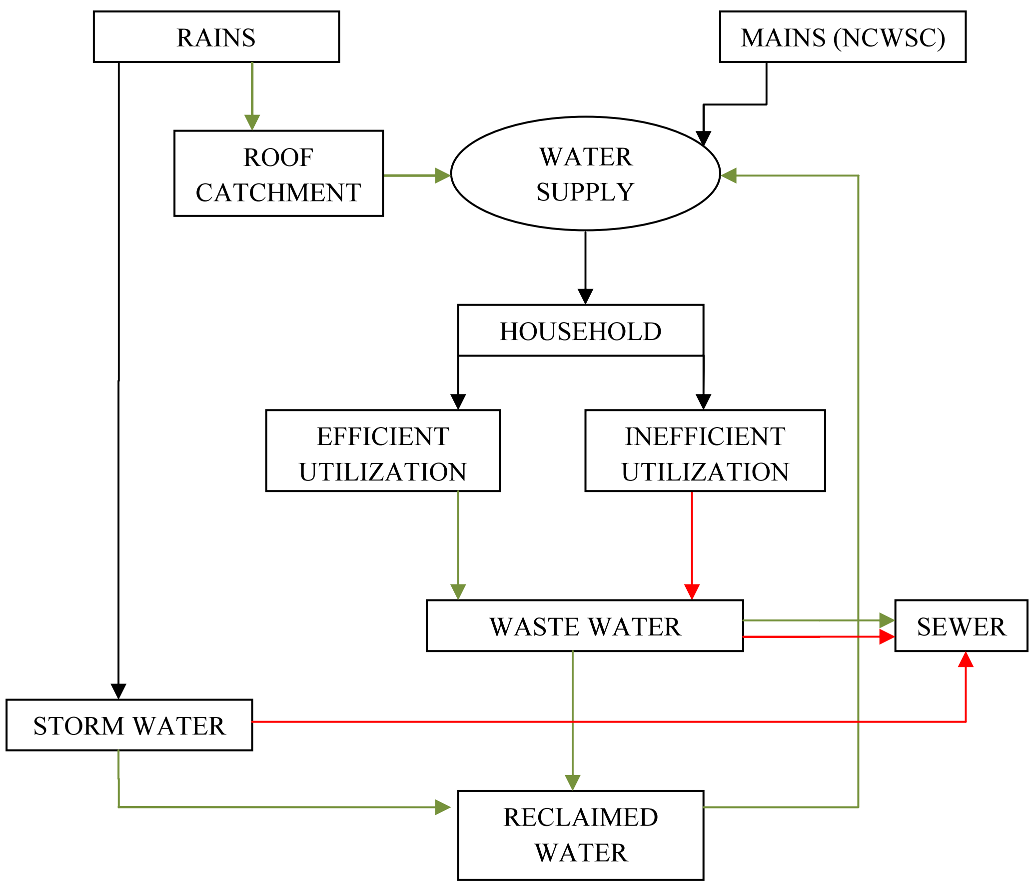


Figure 2.1: Conceptual Framework

Nairobi's water supply can be enhanced by supplementing mains (piped) water with rainwater. The existing situation is such that rain water is allowed to escape as surface run off. Similarly, household water is released into the public sewer after a single use, a situation that reinforces inefficiency of water use. As illustrated in Figure 2.1, the red arrows indicate inefficient use, while the green ones illustrate opportunities for efficient urban water use.

CHAPTER 3: METHODOLOGY

3.0 Overview of Methodology

This chapter details the methodology that was used in this study. It further gives a description of the study area and the study methods used. Together with this, it details the sampling and data analysis procedure that was used.

3.1 Methods and Study Design

3.1.1 Study area

Nairobi County has three districts: Nairobi West, Nairobi North, and Nairobi East (Figure 3.1). These are further divided into eight sub-counties or divisions, namely: Westlands, Nairobi Central, Embakasi, Dagoretti, Kibera, Makadara, Pumwani, and Kasarani (Tibaijuka, 2007).

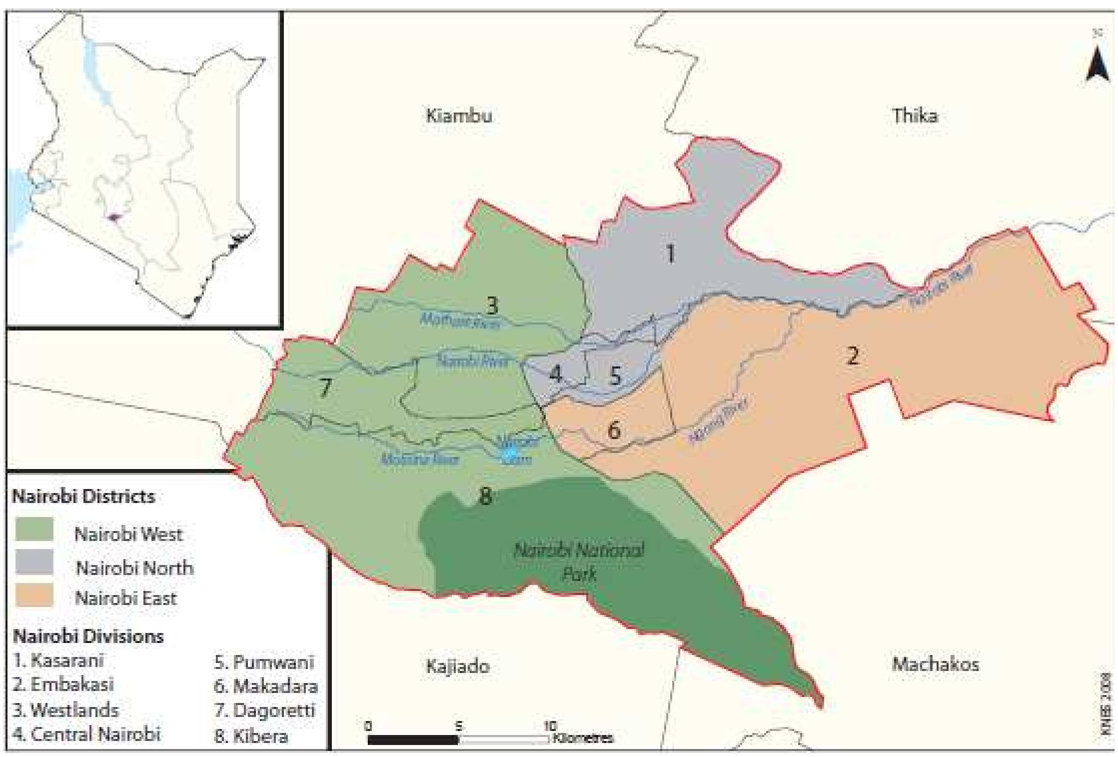


Figure 3.1: Nairobi's administrative divisions (Source: Tibaijuka, 2007)

The study was conducted in two of the divisions: Embakasi and Westlands. The guiding principles behind the selection of these two sub-counties were: 1) accessibility, 2) security, 3) housing typologies. The houses had to be single dwelling units that were similar in size and structure. Out of these two sub-counties, Kangemi, Imara Daima, and Runda estates were randomly selected based on access, security, and house typology. These estates were selected to represent the three income groups existing in Nairobi County as identified by the Kenya National Bureau of Statistics (2008). These income groups include: 1) low income group which comprises of people with monthly earnings and expenditure below Kshs.23,670; 2) middle income group consisting of dwellers with monthly earnings and expenditure between Kshs.23,671 and Kshs.120,000; and 3) upper income whose monthly income is above Kshs.120,000.

3.1.2 Data needs, types, and sources

Data used in this study were both primary and secondary in nature. Primary data were obtained through household surveys of four estates: Kangemi, Imara Daima, Rosslyn Heights, and Runda (in Runda and Rosslyn Heights, only 8 households were successfully administered with the questionnaires out of a target of 90, these estates were therefore excluded from the analysis due to that limitation). Secondary data was gathered from literature review as well as from institutions such as Kenya Meteorological Services, and Nairobi City Water and Sewerage Company. Further information on costing and pricing of plumbing fittings and infrastructure was gathered from the relevant hardware shops as well as through the help of qualified practitioners[4] in the construction industry.

[4] These included: both a Quantity Surveyor and Architects, who were registered by the Board of Registration of Architects and Quantity Surveyors and a Mechanical Engineer.

3.1.3 Sampling procedure and data collection

This study used both multi stage sampling and simple random sampling methods for the field study. From the whole of Nairobi County, three income groups were identified as being low, middle, and upper. Using the KNBS statistics (2008), the estates in each income group were identified. These estates were then randomly selected, based on ease of access. Households in each of these estates were randomly sampled. Due to the complexity of the study, the research focused on single family dwelling units which were mainly bungalows, multiple family residential houses such as apartment blocks and hostels were excluded from the scope of this research. Data collection tools included: questionnaires, interviews schedules, observation, and direct measurements.

Gichagi village in Westlands had a population of about 19,500 people and 6,400 households. Similarly, Imara Daima had 65,000 people with 19,800 households (KNBS, 2008). Most of the houses in Kangemi were shanties with similar size and structure, as opposed to Imara Daima which had flats, bungalows, and maisonettes. British American Tobacco (BAT) estate in Imara Daima was found to have about 1,000 similar bungalows and was selected based on that. Runda and Rosslyn Heights estates in Westlands sub-county had about 1,000 and 40 households respectively. Using the following formula for estimating sample size;

$$n = \frac{Z^2 pq}{(ME)^2} \tag{1}$$

with a Z-value at 10% level of significance (1.645);p and q values of 0.5 each; and a margin of error (ME) of 5%, the minimum sample size was estimated to be 270 households. However, due to problems of accessibility, security, low response rates and inadequate financing, 141 households were successfully sampled and analyzed in both divisions.

3.1.4 Empirical approaches

3.1.4.1Estimating water use efficiency

The United Nations (UN) recommends a daily per capita consumption of between 20 and 50 litres of water for drinking, basic hygiene, and sanitation. This study assumed a daily average threshold of 50 litres per person per day in the middle income households and 25litres per person per day in the low income households, based on the existing consumption patterns that came up from the research. The survey was conducted as outlined below:

a) evaluation of existing household consumption records for sample households over a two year period in order to reconstruct consumption histories. These records were obtained from NCWSC, through their payment records;

b) determination of consumption levels for each sample household for the following profiled activities: toilet, kitchen faucet, other faucets, shower, clothes washer, dish washer, tub, outdoor, and other;

c) observation of any deliberate measures for household water use efficiency per household; and

d) examining any available opportunities for saving water. The following mathematical expressions were used to determine efficiency levels a) per household, and b) per cluster:

$$Ci = \sum_{i=1}^{N} Xi \qquad (2)$$

Household efficiency was determined by:

$$H.E = \frac{Ci}{a} > 1 \qquad (3a - oversupply)$$

$$H.E = \frac{Ci}{a} < 1 \qquad (3b - undersupply)$$

$$H.E = \frac{Ci}{a} = 1 \qquad (3c - optimal\ consumption)$$

The scenario in equation 3*c* indicates efficient consumption

For the low income cluster, efficiency was derived using the mathematical formula (the water supplied was bulked and shared within the estate):

$$\sum_{i=1}^{N(L,M,H)} Ci \rightarrow \frac{TC}{a} \qquad (4)$$

Where: *Ci* denotes the i^{th} cluster that could be low, or middle income, TC= total cluster consumption, *a*= daily per capita threshold (25L for low income households and 50L for middle income households), *n*= number of households, H.E= household efficiency *L*= low income cluster, and *M*= middle income cluster.

3.1.4.2 Calculating Rainwater harvesting potential per household

Rainfall data over the last 10 years of the study area were obtained from the Kenya Meteorological Services. The average annual rainfall over 10 years was used as the mean. The roof area of the sample household was calculated as follows:

$$Roof\ Area\ (A) = \ floor \frac{area}{cosine(pitch[\ degrees])} \qquad (5)$$

The total amount that can be harvested from a roof area of Am^2 was given by:

$$Y = fx\ A\ xT \qquad (6)$$

Where*:* *Y* is the total yield harvested in litres, *f* is the run off coefficient, A = roof area in m^2, and T= total annual rainfall. Ministry of Water and Irrigation Practice Manual for Water Supply Services (2005) proposed a roof run-off coefficient of 0.8; which was used in this case.

Nairobi has a 90% annual rainfall probability (R) or reliability, meaning that in a 10 year period, there is a chance that the tank will not be completely filled up in one year. This should be factored in to the calculations by designing for a bigger tank.

3.1.4.3 Cost benefit analysis of water use efficiency and rainwater harvesting

Three indicators were used to assess the viability of each of the three options under study: 1) water use efficiency, 2) rainwater harvesting, and 3) the do nothing option. These indicators were NPV, IRR, and benefit cost (BC) ratio.

Net Present Value (NPV) is the difference between the present cash inflows and present cash outflows. It compares the value of the dollar today and the value of the same dollar in future. The estimation for NPV is given by;

$$NPV = \sum_{i=1}^{N} \frac{Net\ Benefits_i}{(1+r)^i} - Initial\ Investiment\ (C_0) \qquad (7)$$

Where, NPV = Net Present Value, i= the year, values = net capital flows for the i-th year, N= analytic horizon in years which is ten years in this case, r = the discount rate at which the NPV is being calculated, rates = interest rate at which the NPV is being evaluated, and C_0 = investment or capital outflow at the beginning of the period (usually a negative figure).

Internal rate of return (IRR), on the other hand, is the discount rate that makes the NPV value zero or the discount rate which equates present value of future cash-flows to initial investment. It is given by;

$$Initial\ Investment = \sum_{i=1}^{N} \frac{Values_i}{(1+r)^i} \qquad (8)$$

BC is the ratio of the sum of the discounted benefits to that of initial investments. It is also a measure of assessing the viability of a project. If the ratio is greater than one, the project is viable, otherwise it is unviable. It is given by;

$$BCR = \frac{Present\ Net\ Benefits\ (PNB)}{Initial\ Investiments\ (I)} \qquad (9)$$

Finally, a comparative analysis of the three options was conducted using the results obtained from the NPVs, IRRs, and BCRs.

3.1.5 Data analysis

Descriptive analysis of water use efficiency, rainwater harvesting, and cost benefit analysis in the sampled households was done using SPSS and Microsoft Excel. These have been presented in frequencies, medians, means, and modes. Summaries of the gathered information have been presented in tables and figures. Comparative analysis of the objects under study areas have also been done through ratios, percentages, and proportions.

CHAPTER 4: RESULTS AND DISCUSSION

4.0 Chapter Content

This chapter presents descriptive statistics results from both the household survey and secondary data from the sampled households and other relevant sources, respectively. The study was conducted between April, and June 2014. The study area consisted of Gichagi village in Kangemi division of Westands Sub-county where 71 households were sampled, and Imara Daima estate in Embakasi Sub-county where 70 households were sampled.

Secondary data was collected from the following places: 1) Kenya Meteorological Services who provided rainfall data that covered a period of over 40 years, 2) Nairobi City Water and Sewerage Company, they provided water payment records for Gichagi and Imara Daima estates, and 3) the cost of plumbing fittings and rainwater harvesting infrastructure was obtained from relevant hardware shops.

4.1 Descriptive Statistics

4.1.1 General Household Characteristics

A total of 141 houses were successfully sampled. Majority of the respondents were either household heads or their spouses. Most (80%) of the households had male heads, while 20% were female headed (Figure 4.1). The respondents defined a household head as the person that paid rent and other household bills, hence in the homes where both spouses were present but bills paid by the lady, she was referred to as the household head.

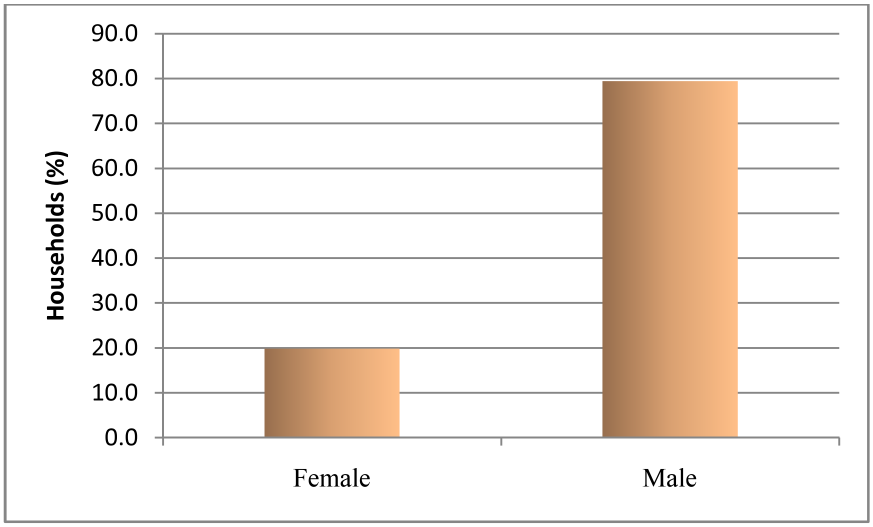


Figure 4.1 Distribution of household heads by gender

Table 4.1 shows the distribution of household heads by age. About 64% of the household heads were aged between 26-35 years followed by 28% in the 36-45 years category. A comparison between the low and middle income groups reveals that 50% of the heads in the low income estates lie between the age of 26-35; this varies slightly from the middle income that has a lower population in this age group but a higher one in the category between 36- 45.

Table 4.1 Distribution of household heads by age

		Age of HH head (n=138)						Total
		18-25	**26-35**	**36-45**	**46-55**	**56-65**	**Above 75**	
Income category	Low income	12	35	15	5	3	0	70
	Middle income	1	29	24	8	5	1	68
Total		13	64	39	13	8	1	138
percent		9.4	46.4	28.3	9.4	5.8	0.7	100

Majority (67%) of the low income earners interviewed are young people aged between 18 and 35 (Figure 4.2). In comparison to this, majority (79%) of middle income earners interviewed were aged between 26 and 45.

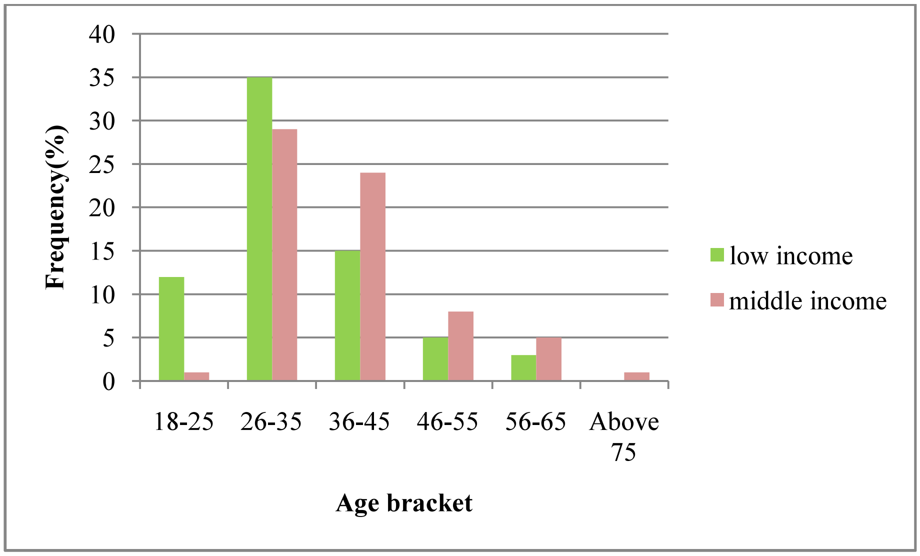


Figure 4.2 Distribution of household heads by age

4.1.2 Education level

Fifty four percent of the respondents in Kangemi were form four graduates, while 29% had gone through primary school up to standard eight. The rest had tertiary education, out of which 6% were university graduates. This varied from the middle income respondents out of which 66% had university and post graduate degrees (Figure 4.3).

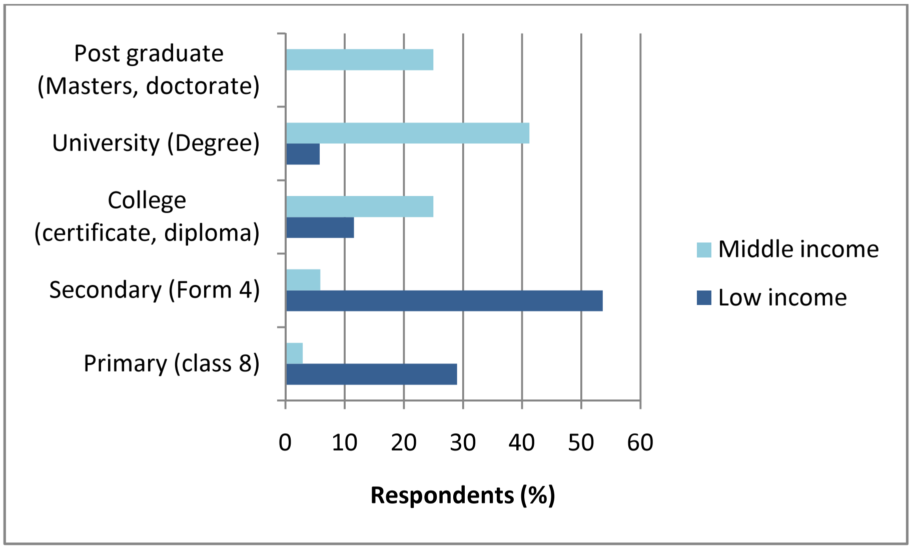


Figure 4.3 Households' education level

4.1.3 Household size

Majority (72%) of the households in both the low income and middle income groups have 1-2 males. In comparison to this, 77% of households have 1-3 females. The minimum size of both genders in the sampled households was 0 while the maximum was 5 and 7 for males and females respectively. The average household had four members, that is, two males and two females (Table 4.2).

Table 4.2 Households' gender distribution

Division	Male (n=141)	Female (n=141)
Mean	1.78	2.11
Standard deviation	1.03	1.33
Minimum	0.00	0.00
Maximum	5.00	7.00

4.1.4 Nature of tenure and duration of tenancy

Three types of tenure were identified in both groups: a) owned with title deed, b) owned without title deed, and c) rented (Table 4.3). Majority of the respondents (83%) lived in rental houses. 16 % owned the houses in which they lived. Less than 1% of the households owned their house but did not have the property ownership title deed.

Table 4.3 Households' nature of tenancy

n=141	Percent
Owned with title	16
Owned without title deed	1
Rented	83
Total	100

Only 1% of the households in the low income group owned the house in which they lived. The rest (99%) lived in rental houses (Figure 4.4). In contrast to this, 31% of the middle income group owned their houses with valid title deeds; while 67% lived in rental houses.

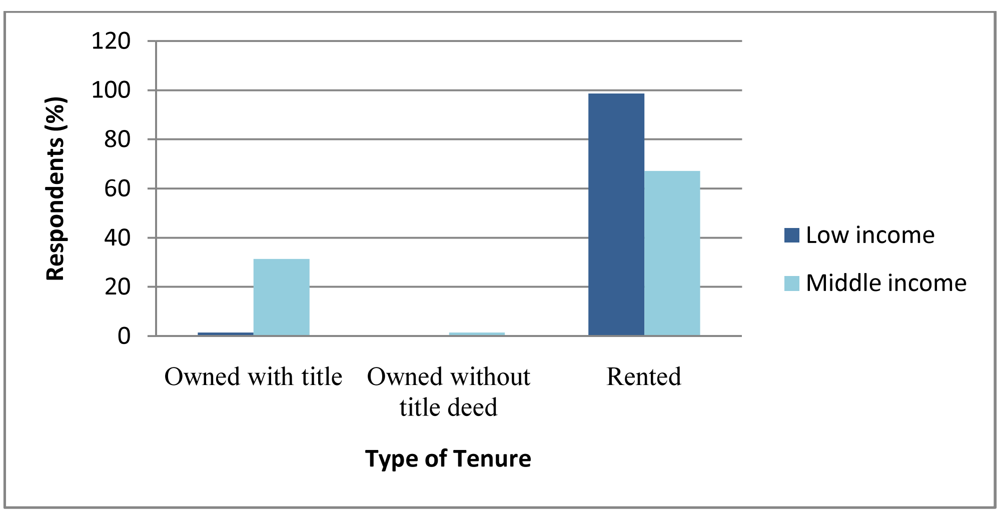


Figure 4.4 Distribution of house tenure systems in the study area

In both groups (49%) of the respondents had lived in their current houses for a maximum period of two years and 40% had lived in their current houses for over five years. Over a half (63%) of the low income respondents had lived in their houses for two years; about 30% had exceeded five years, while 7% had lived in their houses for over two but less than five years.

One third (33%) of the middle income respondents had resided in their houses up to two years while 51% had exceeded five years (Figure 4.5). The middle income respondents therefore exhibited more stability of tenancy and moved houses less frequently when compared with the low income respondents. This could also be attributed to the fact that they have more income hence more stability.

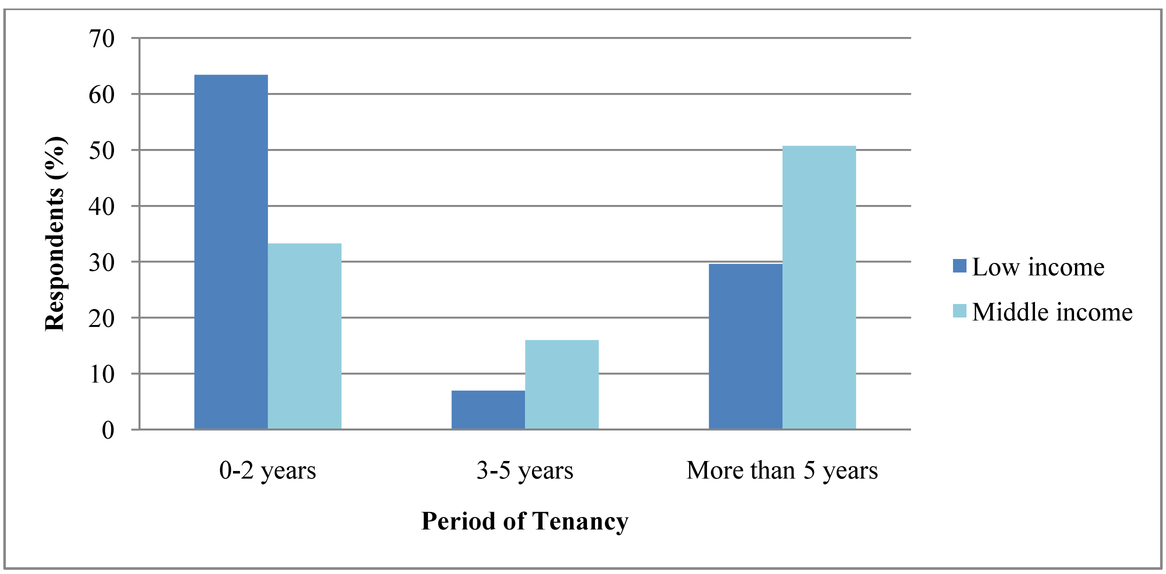


Figure 4.5 Period of residence in the current house

4.1.5 Household income

Formal employment in both groups was 44%, while 36% were self-employed. A further 1% of the respondents had unspecified sources of income. Figure 4.6 illustrates the household sources of income in both the low and middle income groups.

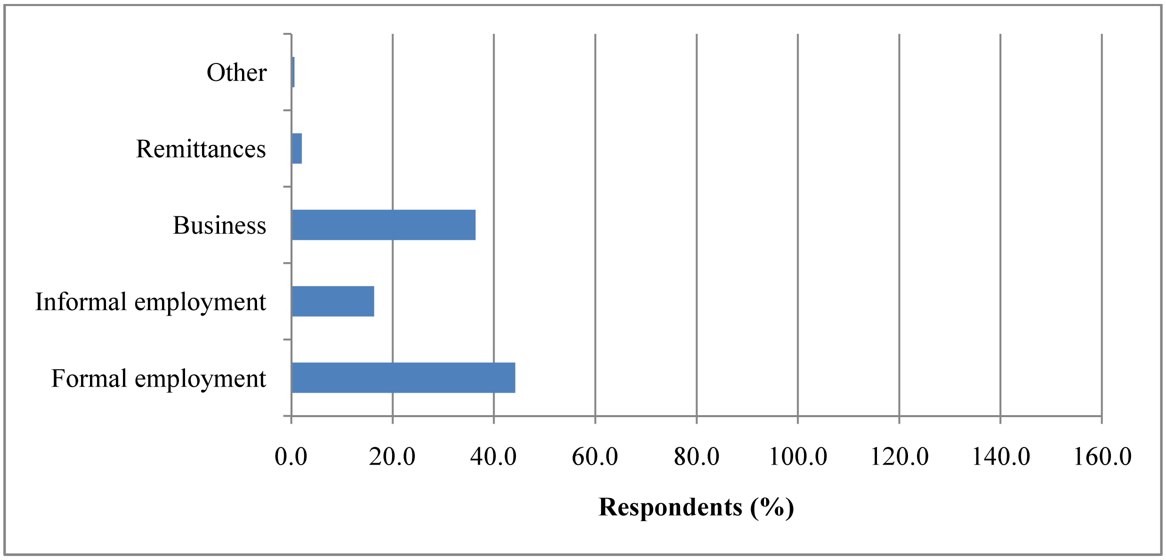


Figure 4.6 Source of household income

When compared, the two groups showed a significant difference in informal employment where 31% of the low income households lay in this category in contrast to only 1% of the middle income. The main sources of income for the middle income respondents were formal employment and businesses. Remittance was not a very common source of income for both groups and was well distributed across the age groups (Figure 4.7).

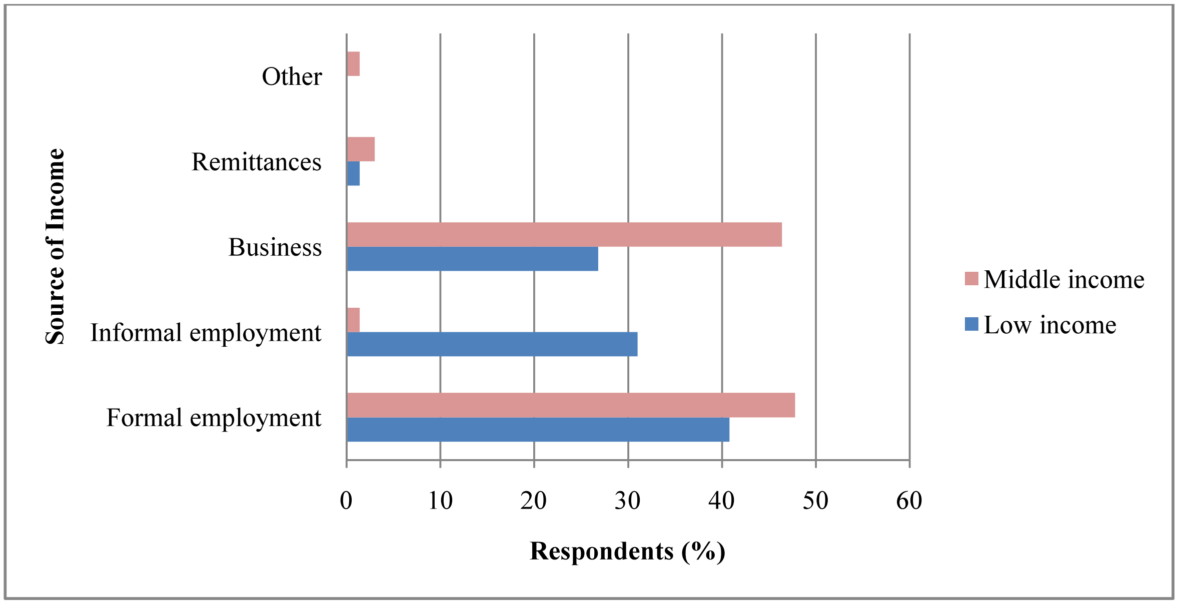


Figure 4.7 Source of household income per cluster

As illustrated in figure 4.8, the most productive age group was 26-35. This age group accounted for 43% of the respondents. Age groups 18-25 and 36-45 account for 23% and 24% of the respondents respectively. Beyond 46 years of age, there is a marked reduction on the levels of gainful formal employment as well as self-employment. The reasons for this could be: a) by age 46, most people have better incomes and can afford to live in other places; b) those that choose to stay do so for the sake of their businesses, and c) some people relocate after retirement.

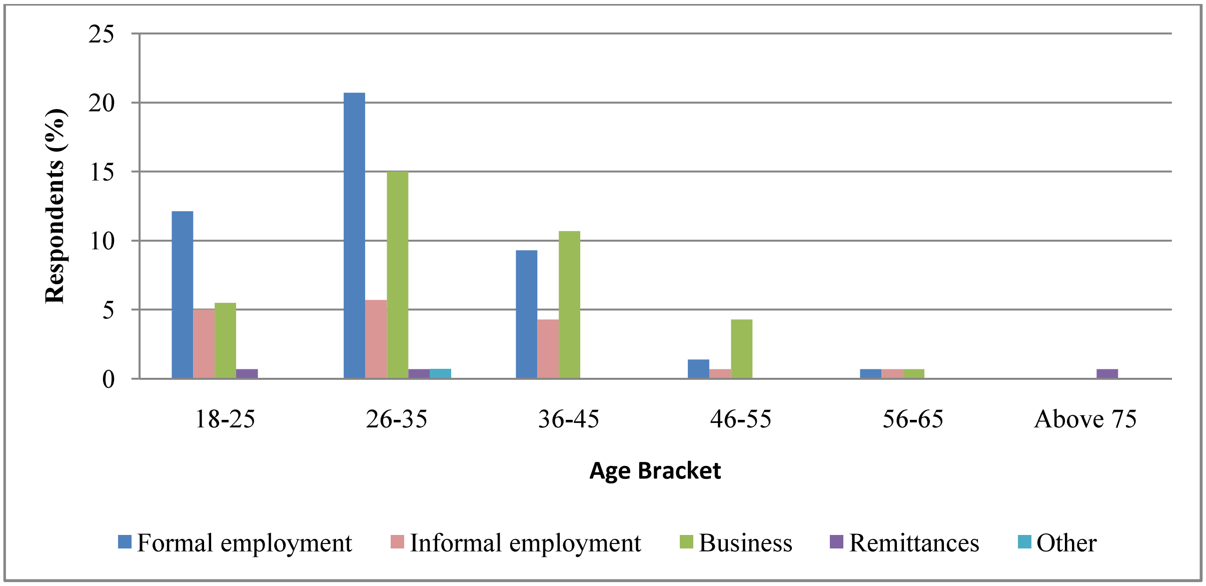


Figure 4.8 Distribution of income sources across age groups

Close to 50% of the respondents in the low income group earned less than 10,000 Kenya shillings per month. A few (7%) were outliers with earnings above the low income monthly threshold of Kshs.23, 670. In the middle income group, 53% had earnings within the middle income monthly range of between Kshs.23, 671 and Kshs.120,000. Sixteen percent exceeded the Kshs.120,000 threshold (Figure 4.9).

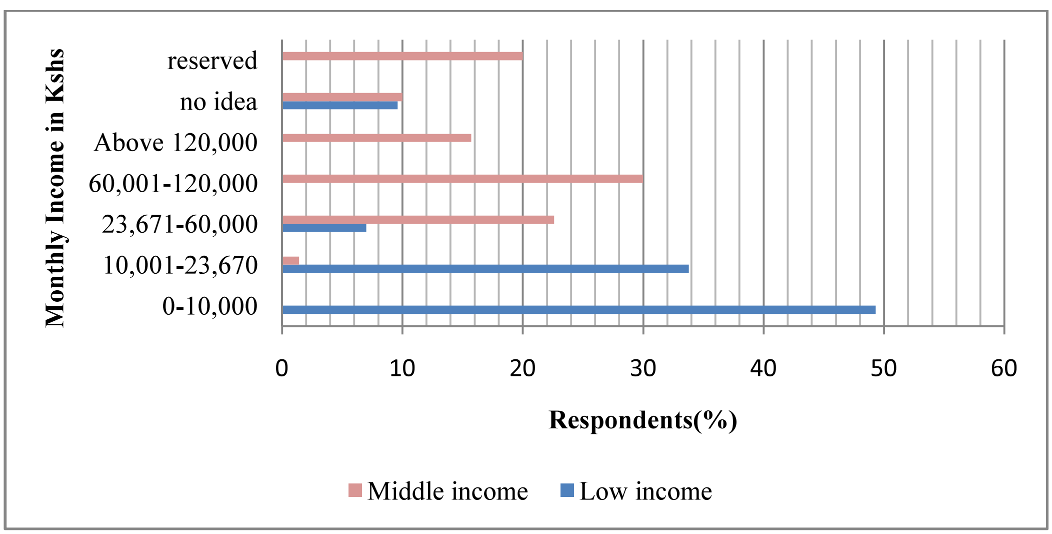


Figure 4.9 Monthly earnings per income group

4.2 Water Use Information

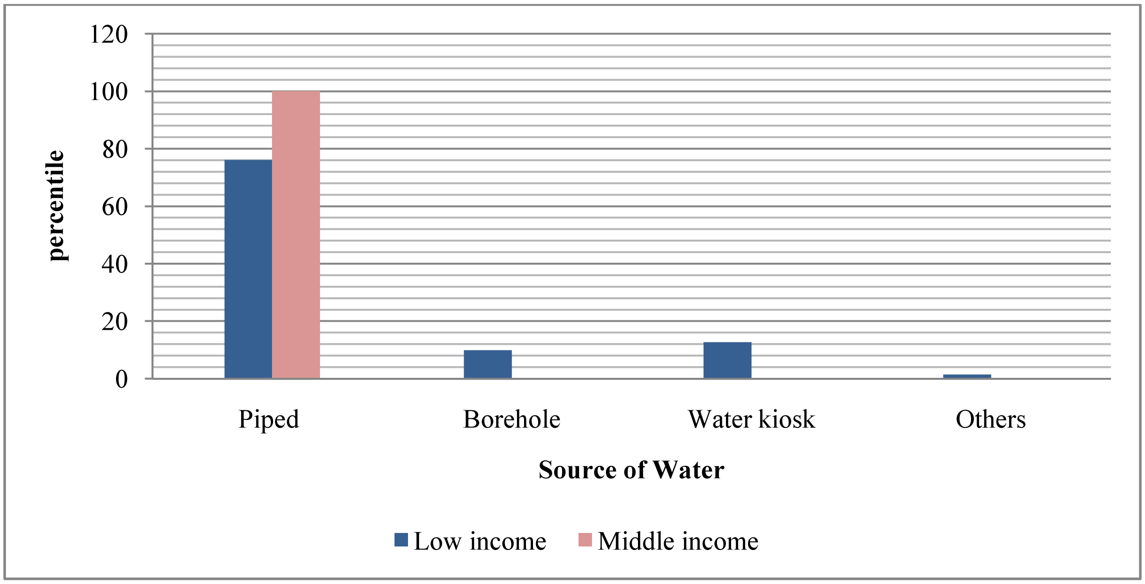


Figure 4.10 Household water supplies

Majority (88%) of the respondents in both groups used water supplied by Nairobi City Water and Sewerage Company (NCWSC). The use of borehole water was limited to 5%. Further, 6% of the respondents relied on supply from water kiosks. All the respondents from the middle income cluster relied on NCWSC water. It was noted that the low income respondents did not have water piped into their houses and shared a common tap within each plot (Figure 4.10).

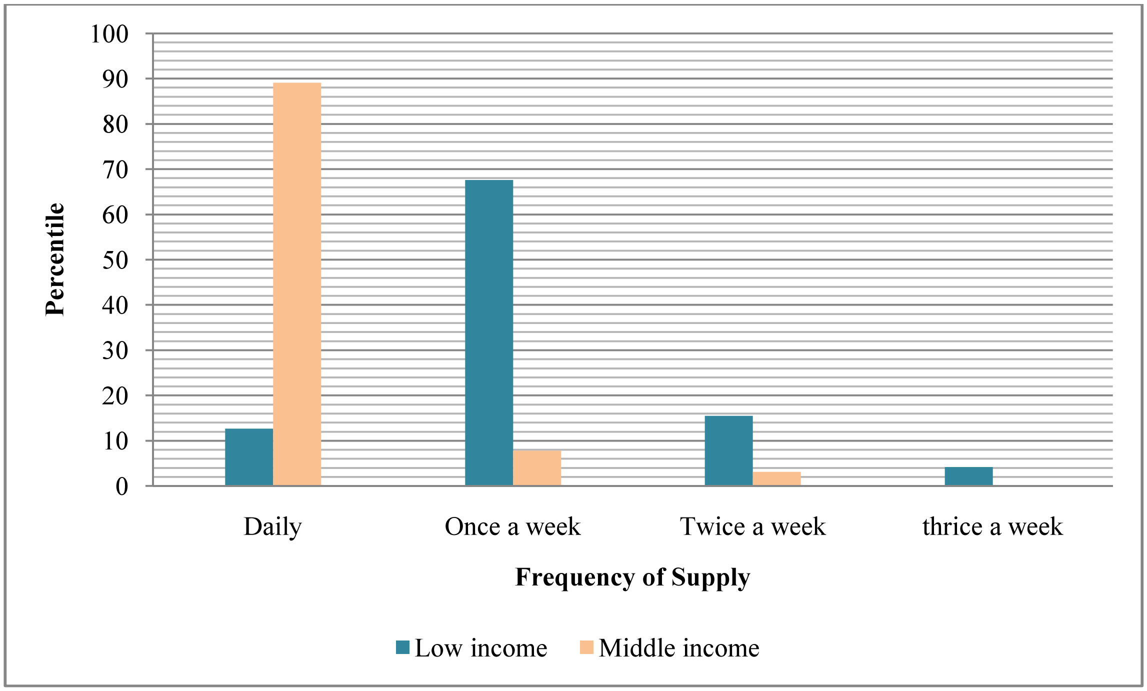


Figure 4.11 Inter-group water supply frequency

Figure 4.11 gives a comparative analysis of the supply frequency within the two groups. Frequency of water supply within the two groups varied significantly, 89% of the middle income respondents reported that they had water supplied to them daily as compared to only 13% low income respondents who got water daily. Most (63%) of the low income respondents reported that they were supplied with NCWSC water once a week. Their landlords controlled the access basically allowing them full access once a week, when they were able to fetch the water and store it in jerry-cans. One is able to fetch as much as their storage can allow. They had to supplement the water when they ran out by purchasing from the local water kiosks or wells.

Information on water expenditure indicated 68% of the low income respondents had no exact figures of expenditure since the water cost was part of the rent that they paid for their houses (Figure 4.12). The monthly rent ranged between Kshs.800 and Kshs.6,000. They also reported that the water they received had to be supplemented from time to time through buying, this was dependent on need. The cost per 20 litre jerry-can was Kshs.5 from water kiosks and Kshs.3 from water wells. The water from wells was cheaper since they felt it was less potable and was used for non-ingestive purposes such as bathing. The cost per jerry-can became significantly higher in cases where the buyer had to contract someone to transport the water for them. It cost them Kshs.10 to transport each jerry-can.

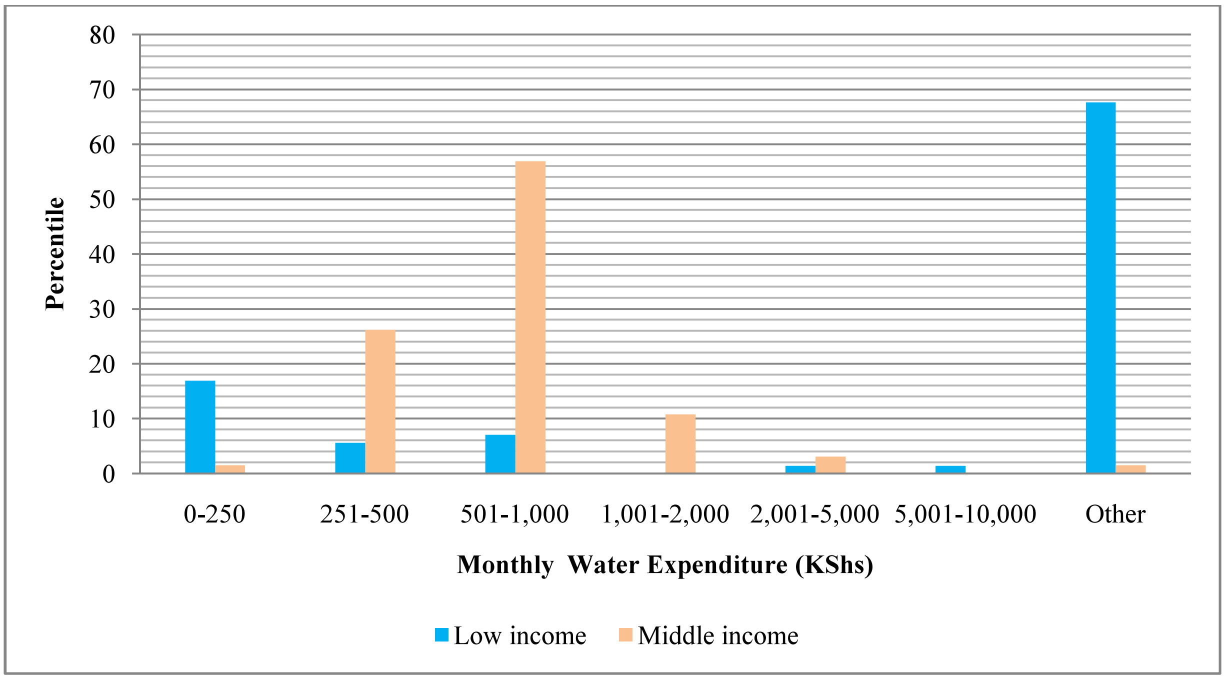


Figure 4.12 Monthly water expenditure per income group

None of the respondents owned a Jacuzzi or used their water on irrigation. The other activities profiled included the following: cooking, drinking, toilet, washing, bathing, and showering. All the middle income respondents used their water to flush toilets as opposed to all the low income respondents who did not own flush toilets and had communal pit latrines in their plots. All the respondents from both groups used the water supplied for cooking and washing. For drinking purposes, majority of the respondents (all low income households, and 97% of the middle income households) said they used the water on that as well. Additionally, 3% of the middle income respondents reported that the water supplied to them was usually contaminated and could therefore not be used for drinking hence they opted to buy bottled water.

All the low income respondents relied on NCWSC water for bathing, as none of them owned a shower. In comparison, most of the middle income respondents used the water both for bathing (99%), and showering (80%). Even though some estimates per activity were provided, most respondents reported that they were not keen on water consumption volumes per activity.

The respondents that had experienced leakages at the household level were 23% in both groups. By cluster, 27% low income respondents reported having experienced leakages when their cisterns and jerry-cans got worn out. Similarly, 20% middle income respondents had experienced leakages (Figure 4.13). In the cases where nothing had been done to stop the leakages, the respondents said they were: a) waiting for NCWSC to do the repairs because they felt the officials tampered with the valves on the meters during readings; b) the pipes were worn out thereby warranting the landlords to fix them. Overall, 14.2% of the respondents (n=141) had experienced a leakage within one month of the research.

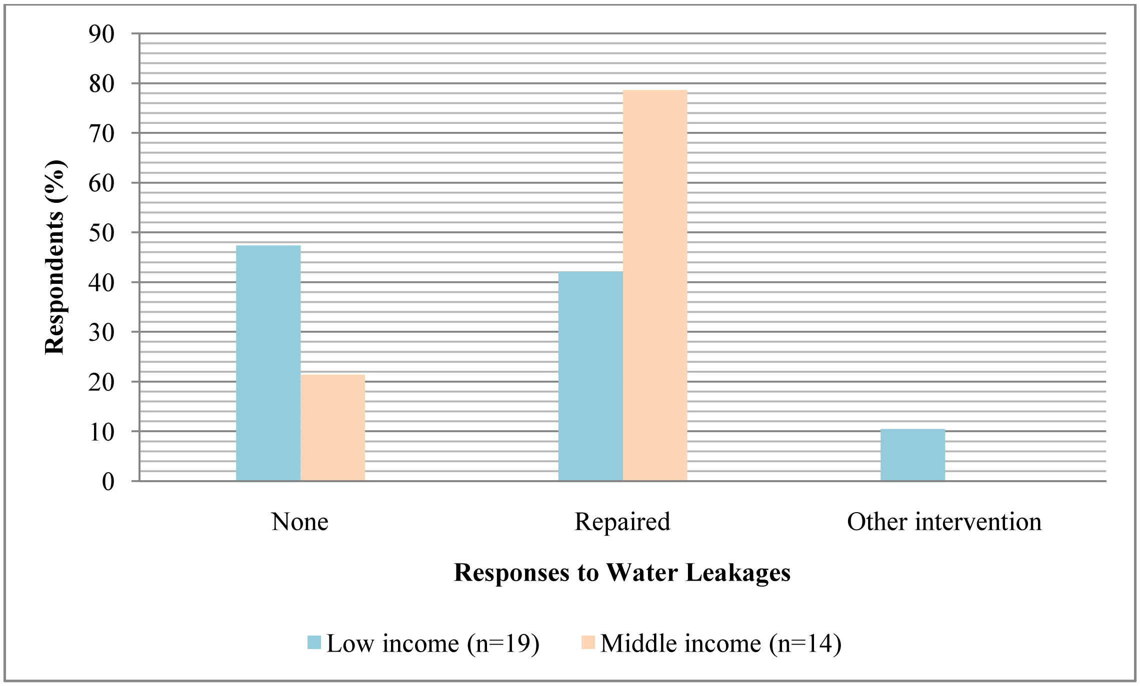


Figure 4.13 Responses to water leakages

Of all the interviewed respondents (n=141), 59% had some information on water saving techniques while 41% had no information at all. Cluster wise, 70% of the middle income respondents had some information on water saving. Over 50% of the low income respondents had no water saving information (Figure 4.14).

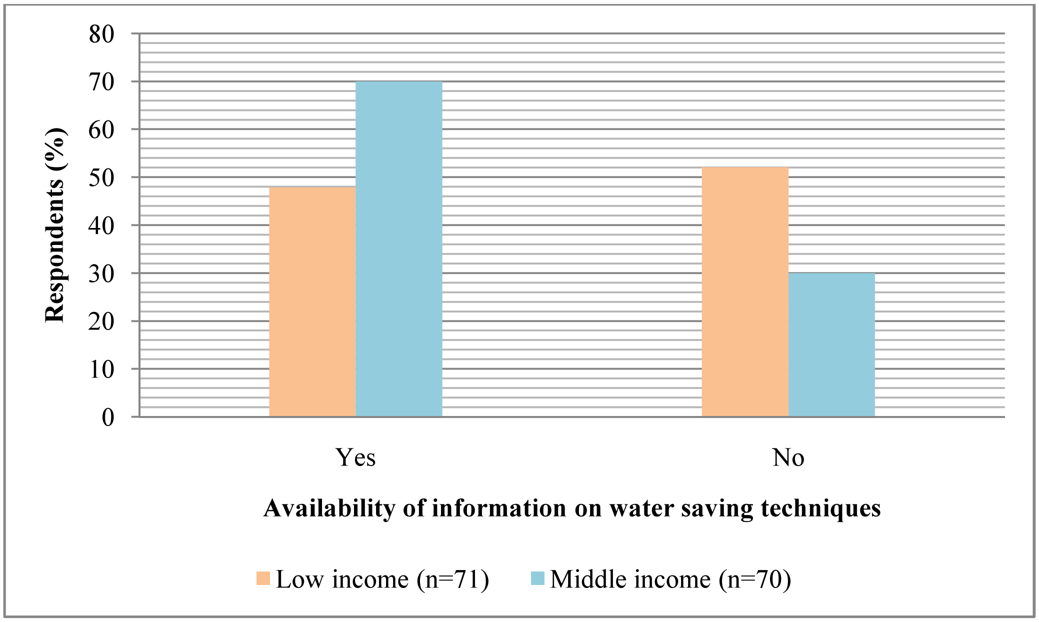


Figure 4.14 Respondents' knowledge on water saving techniques

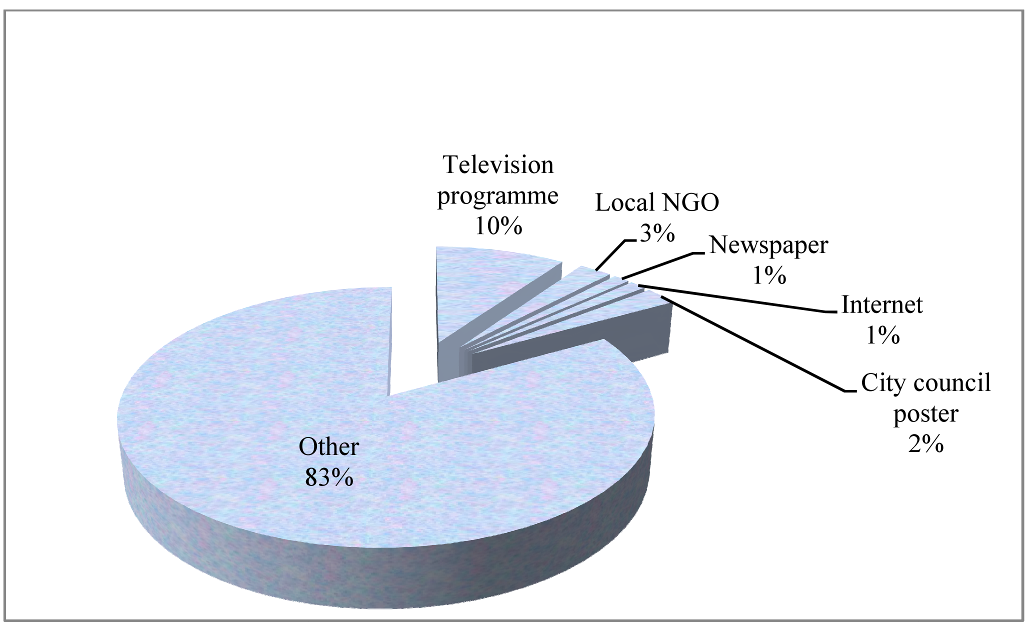


Figure 4.15 Information dissemination distribution on water saving techniques

The source of information on water saving techniques for 83% of the respondents with such information (n=83) was from personal experience through response to water scarcity. The prevailing conditions necessitated that they have such strategies in order to cope with supply shortages. Put together, media, NGO's, and the City County Council/ NCWSC accounted for only 17% of dissemination of information on water saving (Figure 4.15).

About 60% of the respondents had adapted some water saving techniques. Low income respondents had adapted the following techniques for conserving water: a) bulking similar activities together, some of them like laundry were then performed weekly, b) reducing water used on each activity, c) supplementing the available water with other sources such as streams, d) substituting some water intensive activities such as washing the house with carpeting it, e) re-using waste water, f) storing water for future use when available, and g) weighting activities in order of priority. Similarly, the middle income had adapted conservation techniques of their own, these were: a) closing all running taps, b) re-using water, c) reducing water usage per activity, d) reducing shower running time, e) avoiding to run the tap unnecessarily, f) harvesting rain water thereby supplementing their daily supply, g) taking a shower as opposed to bathing and vice versa, h) storing water for future use, and i) repairing leakages.

4.3 Information on Waste Water Re-use

The waste water re-used was mainly gray, 65% of the respondents re-used some of their waste water. Waste water re-use was more popular in the low income households when compared with the middle income ones (Figure 4.16).

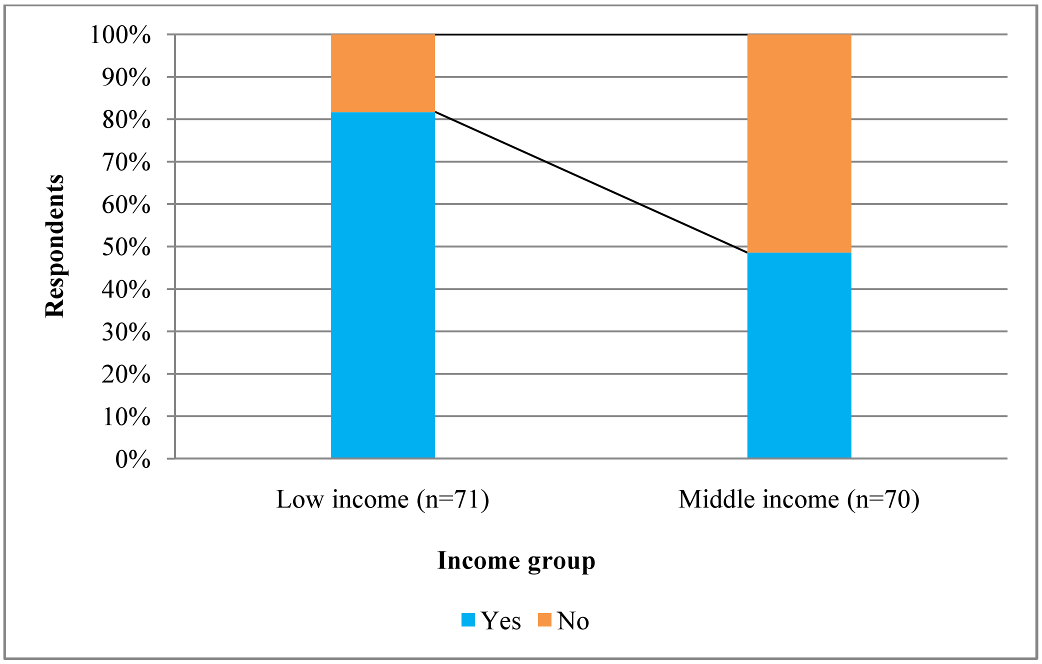


Figure 4.16 Waste water re-use levels per income group

Most of the respondents did not have specific figures on the volumes of water re-used. Only 15% of the respondents tried to estimate the volumes re-used daily. The average amount re-used was between 21-60 litres per day. Of the population that estimated the amount of water re-used, 70% came from the low income cluster (Figure 4.17).

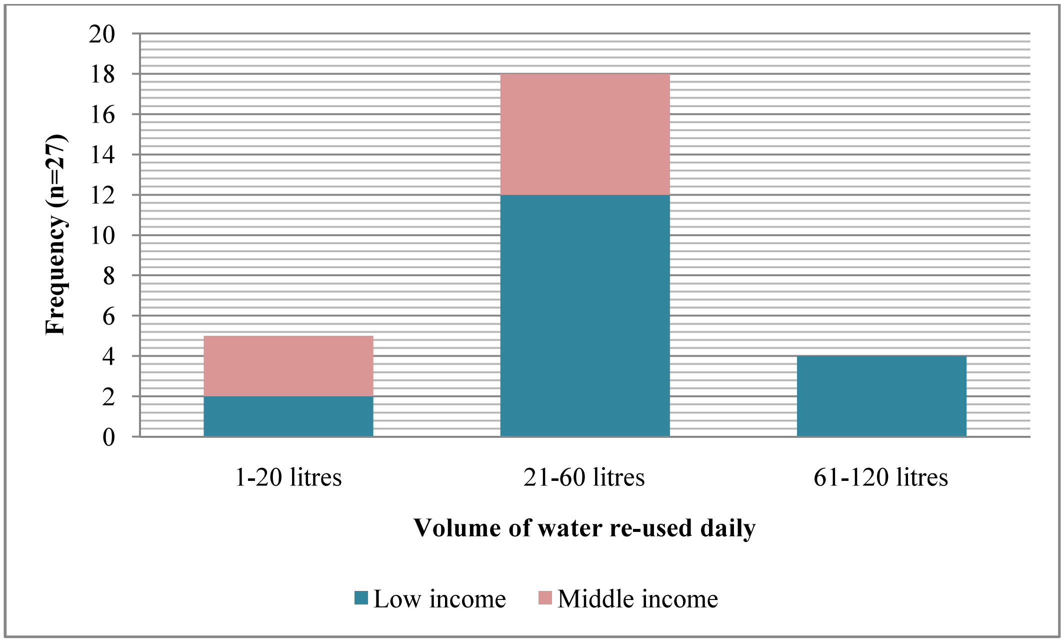


Figure 4.17 Volumetric distribution of water re-use per income group

The two main sources of re-used waste water were identified as: 1) water used on laundry, and 2) water used to wash vegetables. The water obtained from washing vegetables was later used to clean utensils in the low income homes. Water salvaged from laundry found usage in both groups. In the middle income homes it was used to: 1) clean the house, b) clean the car, c) outdoor cleaning, and d) flush the toilet; similarly, in the low income homes it was used to: a) clean the house, b) bathe, c) wash the common areas such as latrines and bathrooms, d) entrepreneurial activities such as charcoal making, and e) re-using it for laundry on the subsequent washings.

None of the low income respondents had a self-contained house as opposed to the middle income that all lived in self-contained houses Figure 4.18). The flush toilets were all single flush, which was an indication that there was no water being saved in toilet flushing. The toilet flush system was taken as an indicator to show that there were no water efficient plumbing installations in the houses apart from showers.

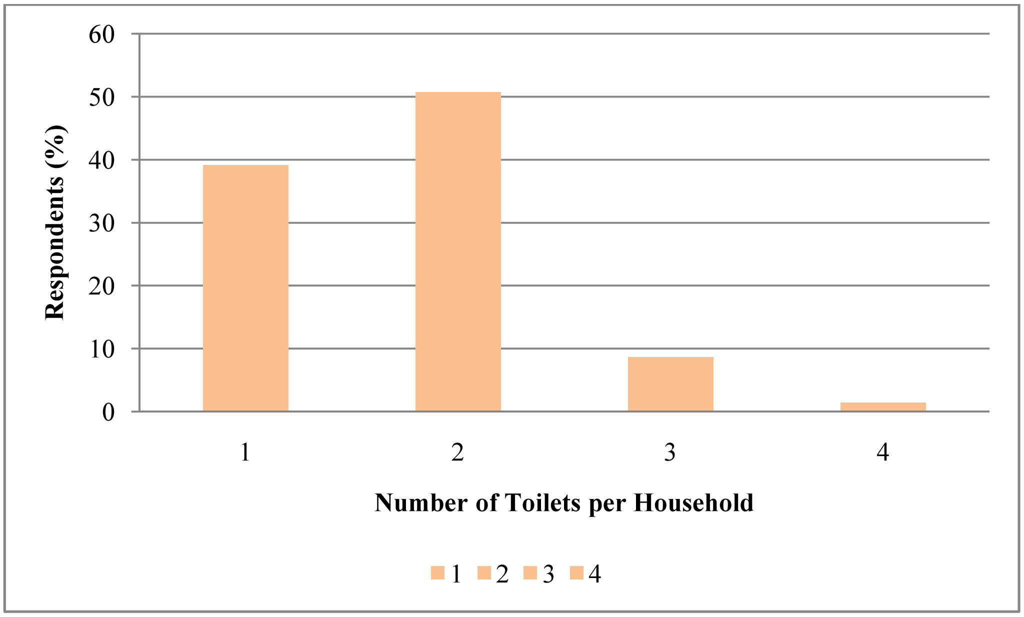


Figure 4.18: Number of toilets per household

An analysis of the frequency of toilet flushing was undertaken (Figure 4.19). The sampled households comprised of 63% of the middle income respondents. If the average toilet cistern is 10 litres, then the amount of water used in 63% of the homes on toilet flushing alone is 4,340 litres. Therefore, the average amount of water used per household per day to flush the toilet is 99 litres.

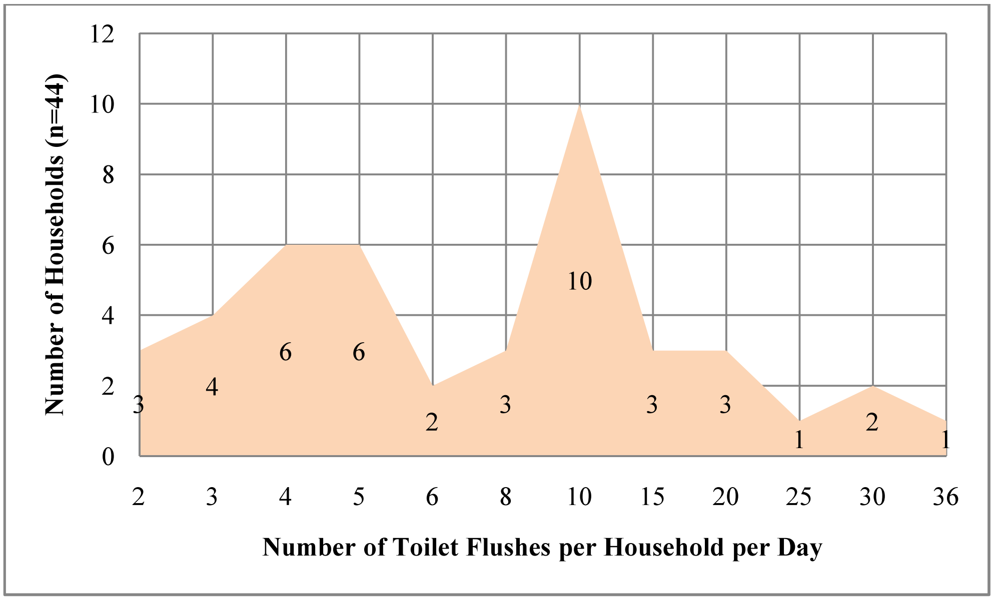


Figure 4.19: Toilet flushing frequency in the middle income group

4.4 Information on Rainwater Harvesting

One of the criteria for selecting the study area was to have estates in each cluster with typical house typologies hence equal roof areas. To estimate the roof area, the following formula was used:

$$Roof\ Area = \ floor \frac{area}{cosine(pitch[22.5\ degrees])}$$

The minimum roof area in the slum housing was 6m^2 while the maximum was 25m^2 with the average mean being 15m^2. In the middle income estate, the roof areas ranged between 60m^2 and 80m^2, the average mean was 65m^2. The roofing material in the low income group was 100% iron sheets, and 100% tiles in the middle income group. Rainwater harvesting was more popular in the low income households at 70% compared to only 30% in the middle income households as shown in Figure 4.20.

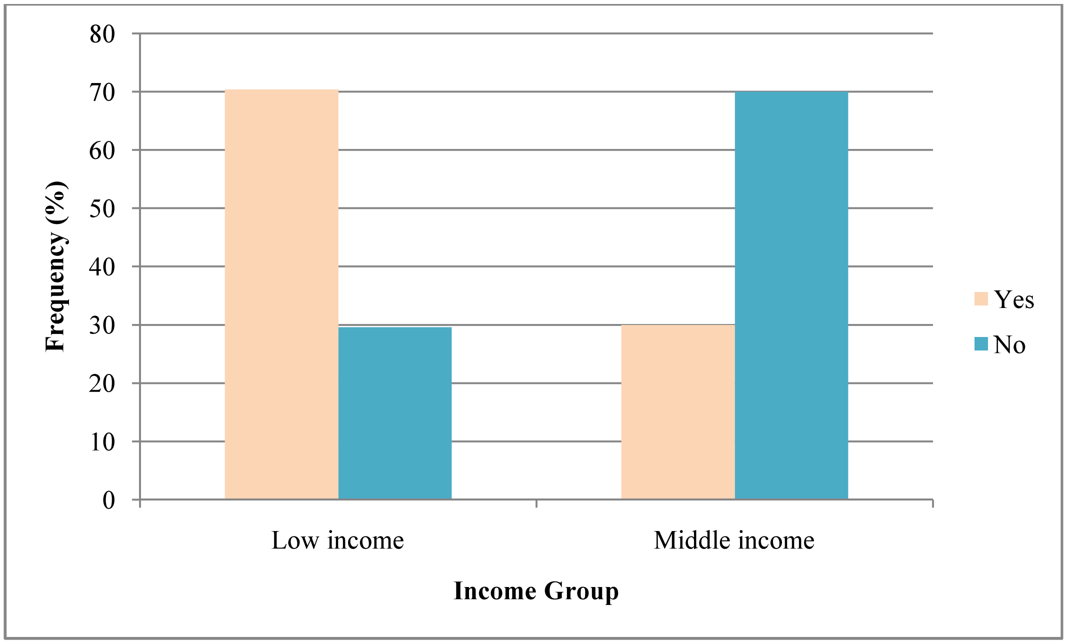


Figure 4.20 Rainwater harvesting frequency

Some of the respondents were not able to estimate the amount of rainwater they harvested; they cited the following reasons for that: a) the amount harvested was dependent on the amount of rainfall received {56% of the low income; and 28.6% of the middle income}; and b) general difficulty in estimating. The average volume of water harvested per household per day in any given rainy season is 13.5 litres. The maximum harvested was 500 litres and the minimum 10 litres.

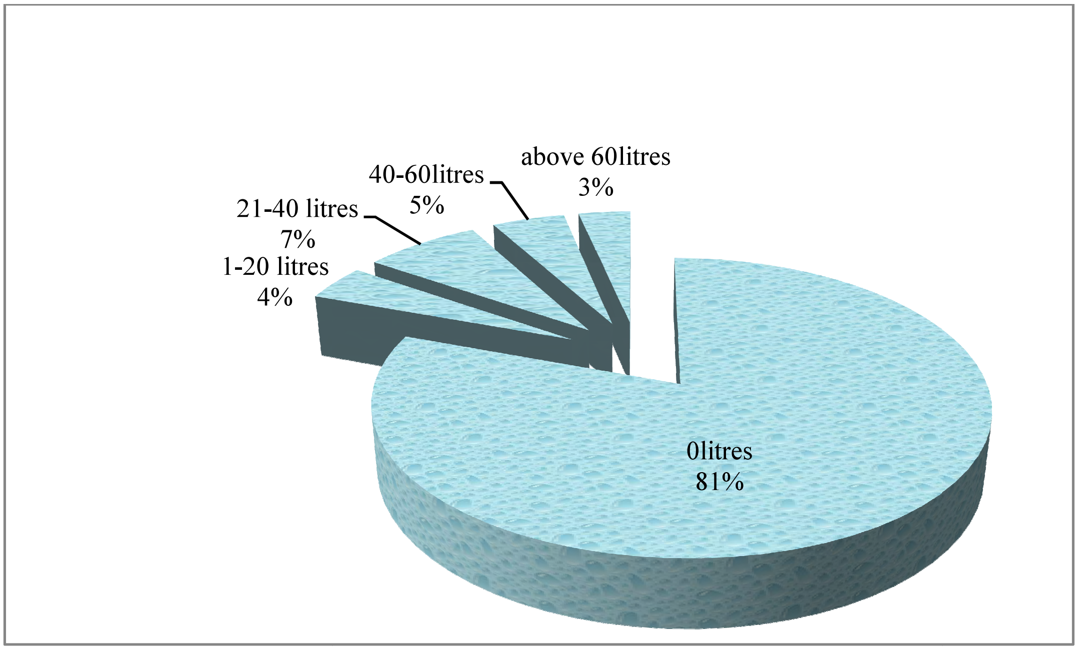
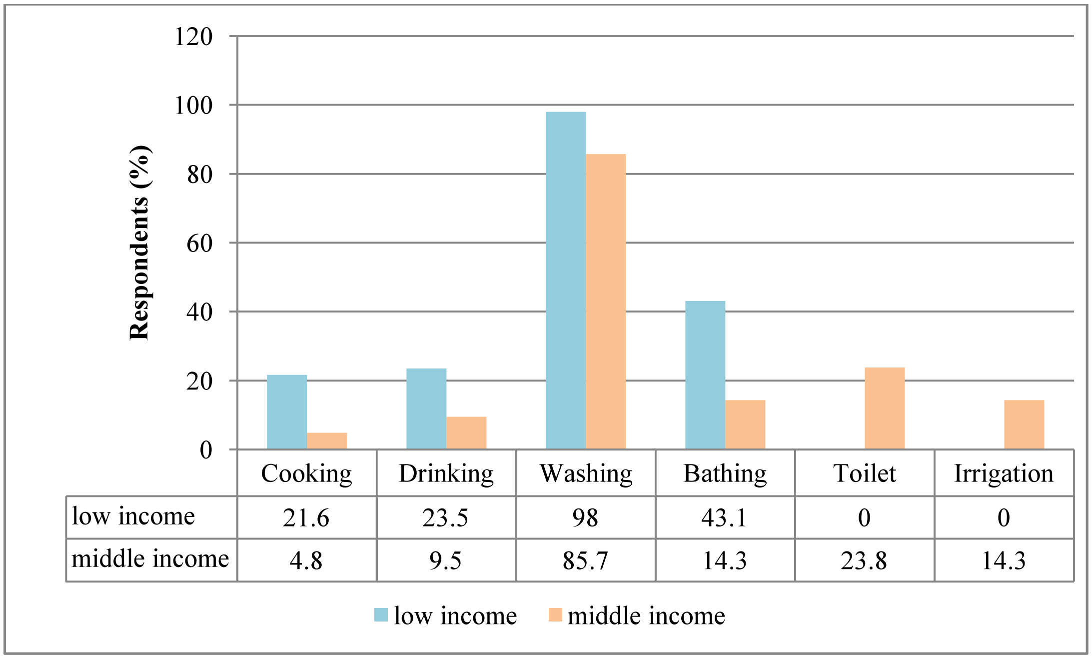


Figure 4.21 Volumes of rainwater harvested per household in each cluster

Five forms of storage were identified. These were: tanks, cisterns, buckets, jerry-cans and basins. Buckets (84%), basins/jerry-cans (6%), and tanks (10%) were the popular forms of storage in the low income group; similarly, the middle income respondents stored harvested water in buckets (48%), tanks (48%), and cisterns (5%).

Rain harvested water was used for cooking, drinking, washing, bathing, flushing the toilet, and irrigation. Majority of the respondents in both the low income and middle income estates used it for washing. The other uses varied across the two groups (Figure 4.22).



	Cooking	Drinking	Washing	Bathing	Toilet	Irrigation
low income	21.6	23.5	98	43.1	0	0
middle income	4.8	9.5	85.7	14.3	23.8	14.3

Figure 4.22Rainwater utilization

The respondents cited the following as limitations to rainwater harvesting: a) fear of diseases such as pneumonia and common cold which tended to occur when they were rained on, b) poor planning of housing in the slum causing houses to be closely built thereby making it difficult to harvest water, c) the water was usually contaminated with the dirt from the roof, c) most of the houses lacked gutters making it difficult to harvest water, d) some thought that they would be prone to malaria if they harvested water and stored it in the houses as this would be a breeding ground for mosquitoes, e) lack of proper storage facilities for water during heavy rains, f) variable rain seasons, g) poor house design, h) general lack of hygiene since the water was usually harvested in the open thereby giving access to dogs which drank from it, and at times neighbours would wash their hands in the harvested water, and i) it was a time consuming exercise which required that the respondents were physically present; something that was not always plausible.

The respondents listed the following points as ways of addressing the limitations to rainwater harvesting: a) inclusion of rainwater harvesting features in house design; these include gutters, storage tanks, and cleaning agents, b) improving the roofing materials to support harvesting of rainwater, c) education on rainwater harvesting, and d) government intervention such as proper slum planning and upgrading.

The respondents who did not harvest rainwater at all gave the following reasons: a) they were seldom at home when it rained, b) they had enough water and therefore saw no need in harvesting rainwater, c) they lacked storage and other supportive infrastructure, d) their type of house tenure was a disincentive to harvesting, and e) they feared atmospheric pollution leading to acidic water, hence putting their health at risk.

4.4.1 Rainfall Trends in Nairobi

Rainfall data was obtained from the Kenya Meteorological Services (Table 4.4). This data included samples from five meteorological stations in Nairobi, namely: Moi Air-Base Eastleigh (MABE), Wilson, Dagoretti, Jomo Kenyatta International Airport (J.K.I.A), and Kabete. To help in deducing rainfall patterns over the years, the data used ranged between January 2003, and December 2012. Four stations were considered for analysis; these were Wilson, J.K.I.A, MABE, and Dagoretti. Kabete was excluded because it had rainfall data for the year 2006 missing.

Table 4.4 Rainfall means for Nairobi County

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual Totals
MABE	45.4	38.0	125.0	155.6	146.4	42.9	10.4	13.9	25.6	72.3	128.7	91.4	895.6
WILSON	43.2	40.2	117.7	164.2	169.6	49.8	7.4	15.5	27.3	66.2	128.8	106.6	936.5
J.K.I.A	41.7	43.3	134.1	164.3	173.8	52.7	8.9	17.9	30.5	67.0	143.3	101.2	978.8
DAGORETTI	31.0	37.1	93.6	173.4	176.5	50.8	8.6	19.2	31.6	67.0	147.2	106.5	942.4
Monthly Mean	40.3	39.6	117.6	164.4	166.6	49.0	8.8	16.6	28.7	68.1	137.0	101.4	938.3

The months of March, April, and May received the most rainfall, followed by October, November, and December. July was the driest month, followed by August and September. Nairobi experiences dry spells[5] in January, February, June, July, August, and September (Figure 4.23). Between 2003 and 2012, Nairobi had an annual rainfall average of 938.3mm.

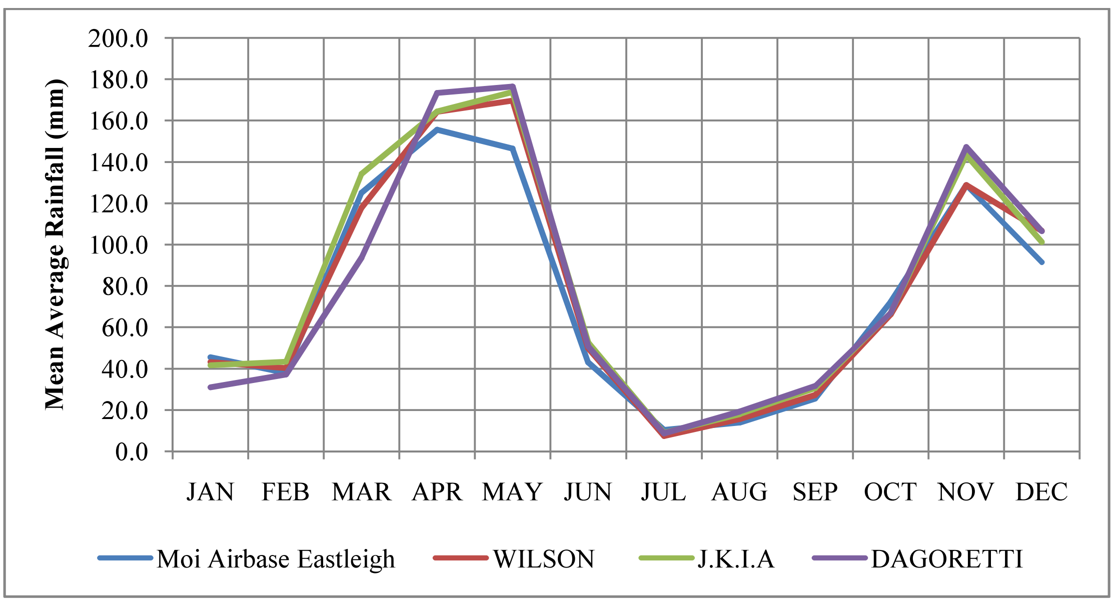


Figure4.23: Rainfall means for different stations in Nairobi County between 2003 and 2012

[5]A dry spell is a period that has the mean monthly rainfall below 50mm (Ministry of Water and Irrigation Practice Manual for Water Supply Services, 2005)

4.4.2 Rainwater Harvesting Potential in Nairobi County

In Kangemi, The total amount that could be harvested from a roof area of Am^2 ($15m^2$) was given by:

$$Y = f(0.8)x\ A(15)\ xT(0.9383m)$$

Where*:* *Y* is the total yield harvested in litres, *f* is the run off co-efficient (0.8), A = roof area in m^2, and T= total annual rainfall in meters.

The average annual yield per household in Kangemi was $11.2m^3$ or 11,200litres. If the average consumption per person per day is assumed to be 25litres, and the average household size is 4 people; then the water harvested per household per year can serve them 112 days. The biggest challenge that would be experienced is storage.

Similarly, in Imara Daima estate, the total amount that could be harvested from a roof area of Am^2 ($65m^2$) was given by:

$$Y = f(0.8)x\ A(65)\ xT(0.9383m)$$

The average annual yield per household in Imara Daima was $48.8m^3$ or 48,800litres. If the average consumption per person per day is assumed to be 50 litres, and the average household size is 4 people; then the water harvested per household per year can serve them 244 days.

4.5 Information on Water Use Efficiency

4.5.1 Household and Cluster Efficiency

The average monthly water consumption per household in Imara Daima estate over the years 2012, and 2013 was 16m^3, and 13.5m^3 respectively. Some months registered zero readings (Figure 4.24). This could be attributed to the fact that the data provided was not well organized. From this information, the average monthly expenditure on water per household per month was Kshs.438 while the average monthly expenditure on sewerage per household per month is Kshs.285.

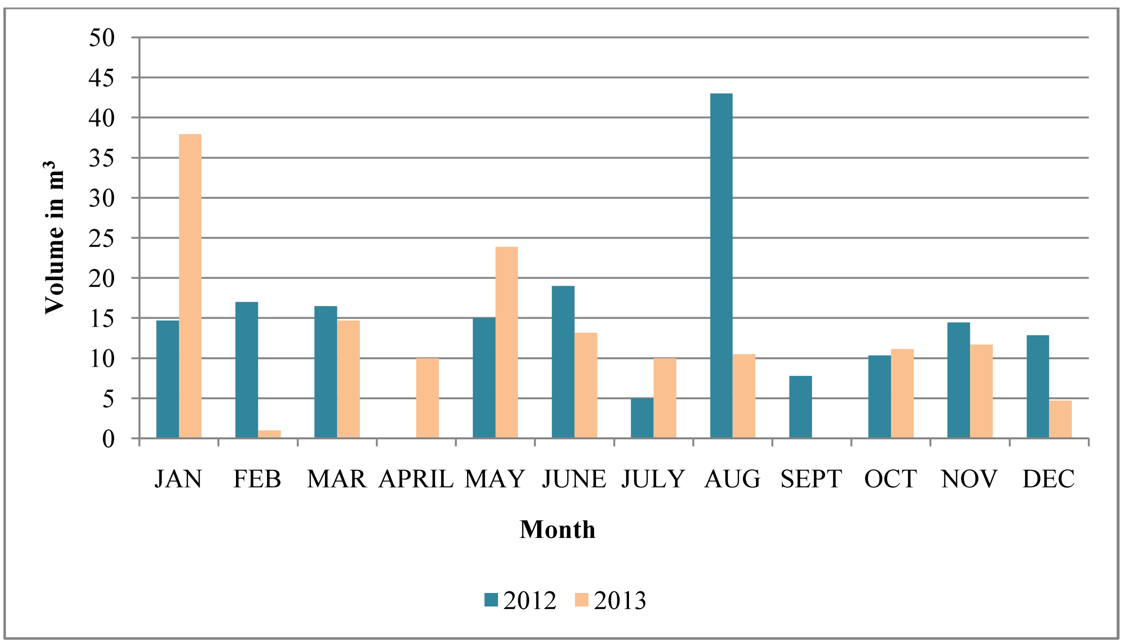


Figure4.24: Monthly household water consumption in Imara Daima estate.

Consumption in Imara Daima was found to be highly wasteful. This was due to the fact the water supplied exceed the amount needed for daily household use. Average Monthly supply was 15,000L which translated to 500L daily supply against an assumed daily consumption of 50L per person translating to 200L for a household of 4.

$$H.E = \frac{Ci}{a} > 1 \qquad\qquad (oversupply)$$

$$H.E = \frac{500}{200} = 2.5 > 1$$

The monthly average consumption in Kangemi was higher compared to Imara Daima. The average consumption in the years 2012, and 2013 was 28.7m^3 and 22.3m^3 respectively (Figure 4.25). This gave an average monthly consumption of 25.5m^3.The higher consumption could be attributed to higher population in Kangemi, a situation that is typical in most informal settlements.

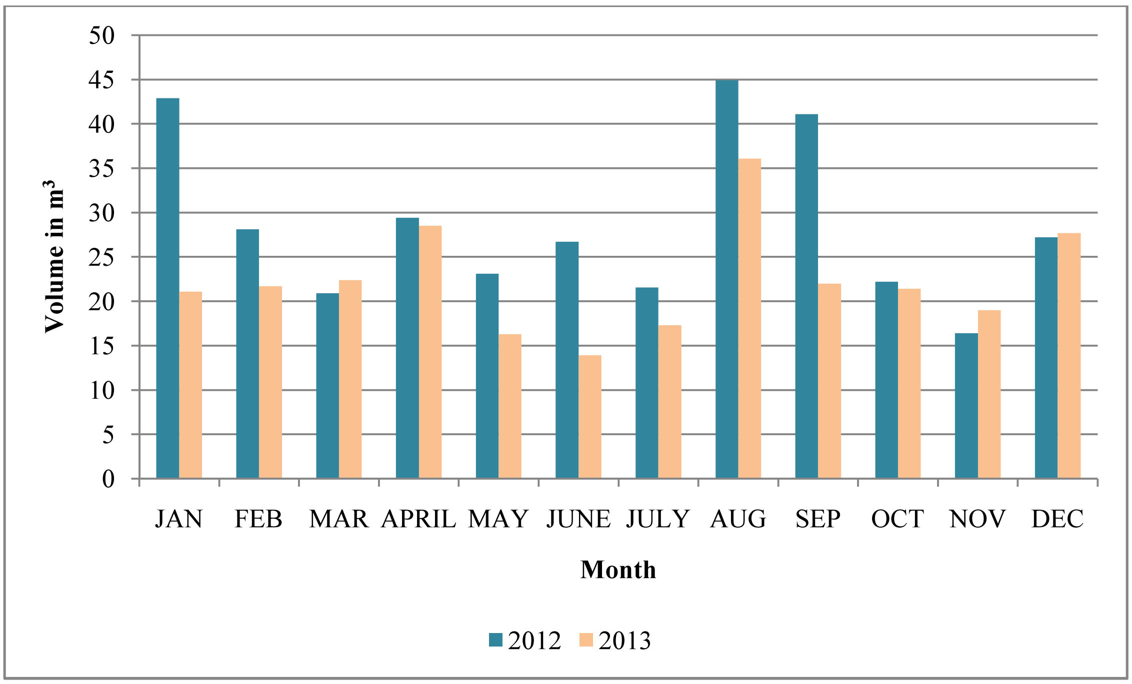


Figure4.25: Monthly household water consumption in Kangemi

Averaged monthly consumption per plot in Kangemi was 25,500L. Each plot had an average of 20 residential units, each with 4 members per household. The assumed daily consumption per person was 25L. The efficiency per plot therefore was:

$$C.E = \frac{25500}{4x20x25} = 12.75 > 1$$

4.6 The Cost Component in Water Use Efficiency

This section analyses the cost aspect of retrofitting using a typical model house at Imara Daima estate. The house is a 60m^2 three bedroomed bungalow with two toilets and two showers. In addition, it has two wash hand basins, one kitchen sink, and an outdoor faucet (Figure 4.26).

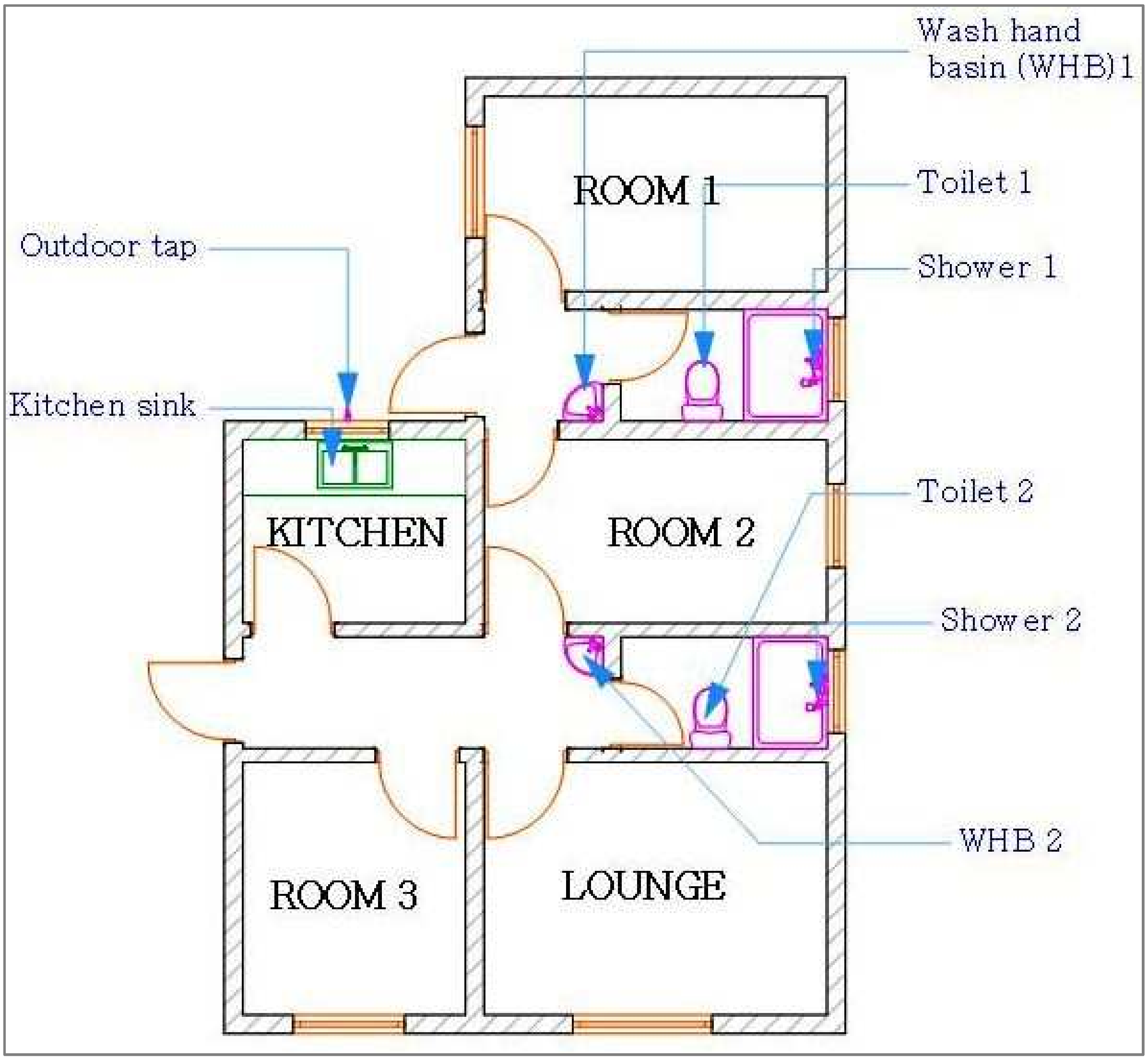


Figure4.26: The rough sketch of the plan of the typical Imara Daima house

NCWSC charges for water and sewerage services according to consumption. The consumption is graduated in such a way that higher consumption attracts higher charges (Table 4.5). The lowest cost is Kshs.18.71 per cubic meter, for monthly consumption of $10m^3$and below, while the highest is Kshs.53.80 per cubic meter for consumption beyond $60m^3$ additional water. This means that, every month, even if the consumption is zero, the client pays Kshs.187.10 in addition to meter rent and value added tax. The meter rent fee is proportionate to the size of the meter, the typical domestic meter being ½ inches and costs Kshs.50 per month. The approved connection deposit for the same meter was Kshs.2,500; this sum was refundable, upon disconnection from water supply if so desired by the client. Other charges included reconnection fee for payment defaulters and exhauster services, which was more applicable in Kangemi since they used pit latrines. The charge for exhauster services in informal settlements was Kshs.4,000.

Table 4.5 Nairobi City Water and Sewerage Company charges for water and sewerage services

WATER		
	Volume consumed in m^3	**Cost per unit (Kshs.)**
1	0-10	18.71
2	11-30	28.07
3	31-60	42.89
4	Over 60	53.80
SEWER		
1	0-10	14.03
2	11-30	21.05
3	31-60	32.17
4	Over 60	40.35

Other water service providers charge differently for water provision in Nairobi. The cost of water is largely dependent on the cost of production and supply to households. Runda Water Limited was one of the service providers sampled in this study. Table 4.6 outlines their charges as gazetted in the year 2009.

Table 4.6 Runda Water Ltd charges for water

Consumption block (m^3)	Cost per m^3 (Kshs.)
0-20	75
21-50	80
51-100	85
Over 100	130

Comparatively, other private business dealers charged differently, depending on the estate and the distance of conveyance. Cart vendors in Imara Daima charge between 25 and 40 shillings. Water supplied by motorized tankers was fixed at Kshs.4,500 per tanker which holds 10,000 litres. Business entities dealing in bottled drinking water were the most expensive, with one litre of water costing up to 50 shillings or more, depending on the brand.

4.6.1 Fittings for Efficient Water Use

Of all the hardware shops sampled (5), none of the sellers had information on tap flow rates. The flow rates and cistern capacities were not found marked anywhere on the fittings, apart from situations where the manufacturer had supplied catalogues to the sellers as is the case with the dual flush toilet which is still carving a niche for itself in the market. The same is the case with the showers, where the manufacturer/ seller were using their water, energy, and cost efficiency as a marketing strategy (Table 4.7).

The flow rates of the faucets were also measured for a sample house. The bathroom faucet recorded a flow rate of 9 L/min when fully opened, while the wash hand basin had an average of 7.5 L/min. The kitchen faucet, even though aerated had a flow rate higher than the bathroom and wash hand basin, which was 10.8 L/min. The half turn tap available was used at the laundry area, and had the highest flow rate of 12 L/min. The shower in the sampled household was the most efficient with a flow rate of 4.5 L/min. This served as an indication that there existed no standardization of plumbing fittings, a situation that could lead to possible water wastage.

Since it was not possible to measure the flow rates of plumbing installations in the study area, this analysis was conducted under the assumption that, with retrofitting, water consumption in the houses could be reduced by 50%. The cost of retrofitting in the middle income households incorporated items a, d, f, and h (Table 4.7), the total cost of which came to Kshs.35,000 inclusive of 40% cost of labour and other overhead costs. This would have the implication that the units of water consumed in middle income households halves from $15m^3$ to about $8m^3$. Consequently, the monthly cost of water and sewage disposal would reduce to Kshs.327 from Kshs.723, a difference of Ksh384.

Table 4.7 Market cost of plumbing fittings

	TYPE OF FITTING	MODEL	CAPACITY/ FLOW RATE	COST PER UNIT	REMARKS
1	Toilet cistern	a) Dual flush	Both half (4.5litres) and full flush (9 litres)	15,000	Is sold as a set consisting of the cistern, toilet bowl, and wash hand basin.
		b) Single flush	10 litres	1,500-plastic 3,000-ceramic	The flush volume is adjustable, done during installation.
2	Kitchen faucet	c) Half turn	-	2,000	
		d) Bib/ Press tap	-	2,000	
		e) Normal tap	-	1,000	
3	Shower head	f) sprinkler	3liters/minute	3.000-6,000	Instant shower
4	Wash hand basin faucet	g) Half turn	-	2,000	
		h) Bib/Press tap	-	2,000	
		i) Normal tap/full turn	-	1,000	

4.6.2 Fittings for Waste Water Re-use

Table 4.8 shows the cost estimates for gray water recycling as calculated by a certified Quantity Surveyor. The costs associated with gray water re-use include: pipe work for collection and distribution, storage tank, pump, and treatment. Treatment cost is excluded because the cost is dependent on various factors, which include: equipment types and capacity, choice of chemical, efficiency of the treatment plant, and amount of discharge per hour per day.

Table 4.8 Cost of gray water re-use

GRAY WATER RE-CYCLING	Option 1	Option 2
Cost Estimate for Civil/Building Works		
Re-collection pipe-work to treatment	65,000.00	65,000.00
Treatment	-	-
Pipe work to reservoir tanks	24,000.00	24,000.00
Reservoir Tanks		-
10,000 litres including base (Ground level)	100,000.00	
10000 litres including base (Underground level)		150,000.00
Distribution		
Water pump to specification	50,000.00	50,000.00
Mains supply to raised distribution tank	20,000.00	20,000.00
High level tanks - 1no *x* 1,000 litres	12,600.00	12,600.00
Total	**271,600.00**	**321,600.00**

As earlier established, the average daily water used on flushing the toilet is 99 litres, while the average monthly water consumption was 14,750 litres per household per month in Imara Daima. Therefore, the estimated monthly toilet consumption is 2,790 litres, 19% of the total monthly supply. Assuming an unaccounted for water (UfW) rate of 20% (2,950), then the estimated recyclable gray water per month is 9,010 litres. If recycled and re-used in the toilet, this water can serve the household for three months. If a reservoir tank for re-use was to be built, it should equal or exceed this capacity.

The cost implication of this is a monthly expenditure of Kshs.275.39 in addition to the fixed charges for the supply of 11,960 litres down from Kshs.560.72, thereby making a saving of Kshs.233.32 in the first month. In subsequent months, the total monthly supply will be 9,010 litres, which will cost Kshs.168.6 for supply and Kshs.39.14 for sewer. In addition to this, there will always be a surplus of recycled water available for sale, or for use on activities such as gardening, and outdoor cleaning (Table 4.9). The total monthly expenditure payable for water and sewerage services will drop to Kshs.105, before addition of meter rent fee and V.A.T.

Table 4.9 Recycled volumes

MONTH	MONTHLY SUPPLY (L)	RECYCLED VOLUME (L)	UPTAKE RATE	20% UfW (L)	SURPLUS (L)	COST OF SURPLUS (KSHS.)-NCWSC RATES
1	14,750	9,010	2,790	2,950	6,220	116.4
2	9,010	7,210	2,790	1,800	5,490	102.7
3	9,010	7,210	2,790	1,800	5,490	102.7
4	9,010	7,210	2,790	1,800	5,490	102.7
5	9,010	7,210	2,790	1,800	5,490	102.7

The cost of recycling may however act as an impediment to this conservation strategy. Taking a life expectancy of 25 years and a five year scrap value for the reservoir tank, the straight line method yielded a depreciation rate of Kshs.57,000 for both options 1 and 2.Results from CBA (Table 4.10) show that if the tanks were to repay themselves within the 25 years, then the price of selling water would be Kshs.7.70 and Kshs.9.30 per litre for both options 1 and 2 respectively.

Table 4.10 CBA results for gray water re-use

OPTION	NPV	IRR	BCR
1	811	14%	0.72
2	1851	15%	0.71

4.6.3 Fittings for Rainwater Harvesting

The costs associated with rainwater harvesting are similar to those in gray water recycling, with the exception that treatment may not be as necessary or to the same degree.

Table 4.11 Cost of domestic rainwater harvesting

RAINWATER HARVESTING	**Option 1**	**Option 2**	
Cost Estimate for Civil/Building Works			
Gutters			
MS Gutters; 35m	28,000.00	28,000.00	
Downpipes; (Average 20m)	10,000.00	10,000.00	
Stopped Ends, Outlets, holder bats)	5,000.00	5,000.00	
Reservoir Tanks			
48,800 litres including base (Ground level)	520,000.00	-	
48,800 litres including base (Underground level)		820,000.00	
2 Level filters	50,000.00	50,000.00	Optional
Distribution			
Water pump to specification	50,000.00	50,000.00	
Mains supply to raised distribution tank	20,000.00	20,000.00	
High level tanks - 1no x 1,000 litres	12,600.00	12,600.00	
Total	**645,600.00**	**945,600.00**	

To conduct CBA analysis, the tanks used in Table 4.11were taken to have an average life span of 25 years, and a scrap value of 5%. Using the straight line method of depreciation, the annual depreciation rate for options 1, and 2 was Kshs.19,760. If the tank has to repay itself within its life span, then a litre of water would need to be valued at Kshs.1.90 in option 1. In option 2 however, a litre of water has to be sold at Kshs.2.60, so as to have the tank repay itself within the same period. A summary of the CBA results is presented in Table 4.12.

Table 4.12 CBA results for domestic rainwater harvesting

OPTION	NPV	IRR	BCR
1	9,926	12%	0.86
2	16,845	12%	0.87

CHAPTER 5: CONCLUSION AND POLICY RECOMMENDATIONS

5.0 Overview of Chapter

This chapter gives a summary of the findings from this study, against the set objectives. It also details the conclusions, and recommendations drawn from the study. Further, it details the policy options that were identified during the research.

5.1 summary of findings

This study was motivated by the need to realize an enhanced water conservation approach to water use in Nairobi that would also encourage equitable distribution amongst competing consumers residing in the city. The findings from the household survey indicated that majority of households in the study area were male-headed, most of the heads were below 45 years of age with the average household in both income groups having been four members, two males and two females. Comparatively, slum dwellers had a lower education level, majority were either primary school or form four graduates, middle income residents were however better educated with majority having been graduate and post graduate degree holders. The type of tenure system for both groups was rental; the middle income respondents however showed more stability and were less likely to move houses very often. Income in both groups came from two sources: formal employment and businesses.

The source of water for both groups was mainly NCWSC. Rainwater had been greatly underused, and the water harvested had been very minimal when compared with the actual potential in each income group. However, the safety of rainwater was unknown, making the respondents mistrust the water. Although gray water was already being re-used and was more common with the low income households, the cost of recycling water, as well as harvesting rainwater was high and would possibly not make economic sense to consumers, especially since they were mostly living in rental houses.

Of the sampled population, 23% had experienced water leakages, but felt it was not their responsibility to carry out repairs, but that of either the landlord or water service provider. Those respondents who had some information on water saving techniques were almost 60%, with the middle income earners having been more conversant with these techniques. But, dissemination of water saving information was very minimal, with the media, government, and NGOs altogether having accounted for only 17% of the information disseminated.

5.2 Conclusion

From the study, it can be concluded that the existing water market in Nairobi County is hugely fragmented. Water from NCWSC is the lowest priced within the market. This has the implication that: a) consumers do not have an incentive to conserve water because of its low price; and b) there is no accountability on the account of suppliers to the consumers. Consumers lacked the incentive to conserve water and diversify supply owing to the fact that water supplied by NCWSC was heavily subsidized. The cost of water supplied by the NCWSC did not therefore reflect the real cost of water production. In addition to this, rainwater harvesting and gray water recycling was an expensive option that most consumers would not be willing to opt for unless they were given reason to.

The type of house tenure existing to most of the consumers was rental, this acted as a limitation to diversification of water supply through: a) retrofitting, b) re-use, and c) rainwater harvesting. Unless the housing developers are made to implement this infrastructurally, tenants would have to continue to use the system as it was. Similarly, lack of proper and educative water sensitization initiatives had resulted in a lack of drive to conserve water. The government, media, NGO's, and other stakeholders have the duty of educating the masses on such important initiatives in order to create awareness amongst the consumers.

Diversification is the key to obtaining water autonomy in Nairobi, but more needs to be done in terms of research to determine the best and most cost effective means of diversification. Already, too much potable water (20%) is being rendered dirty through use in toilets in the middle income households; this is unacceptable given that other city dwellers are facing the challenge of access to clean adequate water. Similarly, rainwater is a viable option that can be used to cushion consumers during supply shocks and should be investigated for safety.

5.2 Policy Options

Kenya is already mapped as a water scarce nation with 647m^3 per capita, this amount is expected to drop to 250m^3 per capita by the year 2030 (National Water Quality Management Strategy (NWQMS) (2012 – 2016), 2012). There is need therefore, to monitor and ensure that available scarce resources are utilized optimally. Seldom is household water utilization considered in the quest to secure proper and efficient water use. The National Water Quality Management Strategy 2012-2016 and other policy documents need to be updated to ensure that domestic water consumption is included in the monitoring schedule. This will possibly have two effects 1) there is likely to be enhanced efficiency of use at the household level and 2) reduced pollution of water catchment areas through uncontrolled household waste water disposal.

The government needs to put in place incentives for gray water re-use. Such incentives should include subsidies on water efficient plumbing fittings, green taxes which will act to ensure that polluters pay for their damage to the environment through careless disposal of waste water, and tax rebates for consumers who have put in place systems that enhance efficient water use. Technology should be used to ensure that consumption can be monitored and reduced where necessary. The consumption and flow rates of plumbing fittings should also be standardized and dealers in such fittings should be required by law to be conversant with these settings and to have basic training in water efficient plumbing fittings. The Building Code should be revised to ensure that plumbing fittings specified by architects and mechanical engineers for all new structures meet basic water conservation requirements. Owners of old structures should be given incentives to retrofit and install water efficient fittings.

The National Water Quality Management Strategy targeting the period between 2012 and 2016 recognizes rainwater as an important resource that needs to be enhanced. Rainwater from roofs and other hard surfaces should be dealt with in either of, or both of these two ways: a) all new and old structures should allow for underground percolation of all the water in order to replenish the receding water table. This should be a requirement by the relevant bodies, that offer approval of all construction projects; and b) all new buildings should have an allowance for rainwater harvesting system that can harvest water and store it for use during shortages to supplement the existing supply. Business entities such as housing estates that rely on borehole water should be required through law and policy to replenish the water abstracted by a certain percentage, using rainwater based on their roof catchment capacity. This will go a long way in discouraging wasteful use of the finite resource. As consumers embrace rainwater use, there's need for studies to be conducted to determine the safety of this water and how best it can be made fit for human consumption. In addition, tax subsidies should be introduced on rain harvesting systems in order to encourage their installation.

There's need for a policy to harmonize water prices within the industry so as to have water prices, reflecting the real cost of water. This will act as a disincentive to wasteful utilization, and also encourage consumers and developers to embrace green water consumption practices. These practices may include rainwater harvesting and gray water re-use, as well as installation of efficient plumbing fittings.

Finally, public awareness should be conducted by the various stakeholders involved in the water supply chain. Consumers need to be sensitized on the finiteness of water as a naturally occurring resource and the need for efficient management of household water. Not much research has been ongoing when it comes to domestic water utilization, Nairobi County on its part is yet to develop a policy that supports efficient water use and rainwater harvesting at the household level. This will be achieved through conducting targeted research, which should be the supporting pillar of the County's water consumption patterns.

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APPENDIX 1: HOUSEHOLD QUESTIONNAIRE

ENHANCING HOUSEHOLD WATER USE EFFICIENCY IN NAIROBI COUNTY

HOUSEHOLD SURVEY QUESTIONNAIRE

All around the globe, there is growing pressure on water resources due to pollution, climate change, and rapid population growth. Many developing countries may not be able to provide adequate clean water for their residents in the future. Kenya as a country already suffers water scarcity in various parts, both rural and urban, by the year 2025, the amount of water available to each person per year will be down to a quarter of what the United Nations recommends. It is against this backdrop that the researcher, a student at the University of Nairobi seeks to explore opportunities available for improvement in water use, and distribution within Nairobi County.

Participation in this research is voluntary, and confidentiality of the information provided is assured. Research authorization has been granted by the Ministry of Education through the National Commission for Science, Technology, and Innovation, the University of Nairobi, the County Commissioner, the County Director of Education, and all other the relevant authorities. It is estimated that this interview will take an average of 10-20 minutes. Your participation in this research is much appreciated.

SECTION 1

1.1 Questionnaire Details

Questionnaire Number: Date

Enumerator's name Sub-County:

Time at start of interview: Estate:

Time at end if interview: House number (optional): Meter number (optional):

HHID Number: House typology:

1.2 Respondent's Details

Name of the respondent (optional)

Respondent's age

A=18-25

B= 26-35

C= 36-45

D= 46- 55

E=56-65

F=66-75

G=above 75

Respondent's years of residence in the house A= <1

B= 1-2

C= 3-4

D= 5>

1.3 Household Characteristics

Household (HH) Characteristics

1.3.1 Relation of respondent to HH head (use Codes D)

1.3.2 Gender of HH head (sex) (Codes A)

1.3.3 Age of HH head (years) A=18-25

B= 26-35

C= 36-45

D= 46- 55

E=56-65

F=66-75

G=above 75

1.3.4 Marital Status of HH head (Codes B)

1.3.5 Education level of HH head (years) Codes C

1.3.6 Education level of HH member (years) (Codes C)

1.3.7 Household size

No. of males:

No. of females:

1.3.8 Duration of HH residence in the house (years)

A= <1

B= 1-2

C= 3-4

D= 5>

1.3.9 Type of tenure of HH

1= Owned with title

2= Owned without title deed

3= Rented

4= Parent / relative

5= Government / communal / cooperative

6= Other (Specify)________________

Codes A	Codes B	Codes C	Codes D	
0. Female 1. Male	1. Married living with spouse 2. Married but spouse away 3. Divorced/separated 4. Widow/widower 5. Single 6. Other, specify……	1. Primary (class 8) 2.Secondary (Form 4) 3. College (certificate, diploma) 4. University (Degree) 5. post graduate (masters, doctorate) 6. Other (clarify)…………………………………	1.Household head 2. Spouse 3. Son/daughter 4. Son/daughter in law 5. Parent 6. Broth/sister 7. Broth/sister in-law	8. Mother/'father in law 9. Grand child 10. grand parent 11. Aunt/Uncle 12. Nephew/niece 13. Hired worker 14. Other, specify……

1.4 Household Income

1.4.1 What is the household's main source of income?

1= formal employment

2= informal employment

		3= Business
		4=remittances
		5= Other (specify) ________________
		________________________________
1.4.2	What is your household's estimated monthly income (in Kshs.)?	A= 0-23,670
		B= 23,671-120,000
		C= above 120,000

SECTION 2

2.1 Water Use Information

2.1.1	Household's source of water	1= piped (City County Council)
		2= rain
		3= stream
		4=borehole
		5= well
		6= Water kiosk
		7= communal water point
		8= motorized supply
		9= Other (specify) ______________
2.1.2	Frequency of water supply.	A= daily
		B=once a week
		C=twice a week

		F=weekly
		E=Fortnightly
		F= Monthly
		G=other(specify)
2.1.3	Household's monthly expenditure on water (the average cost).	A= 0-250
		B= 251-500
		C= 501-1000
		D= 1001-2000
		E= 2001-5000
		F= 5001-10,000
		G=10,001-15,000
		H=15,001-20,000
		I= over 20,000

		J=other		
2.1.4	What activities do you use your water on? (use code 1-9, with 1 being the most significant and 9 the least significant activity to use water on)	1=cooking		
		2=drinking		
		3=toilet		
		4=washing		
		5=bathing		
		6=shower		
		7=irrigation		
		8=bathtub/ Jacuzzi		
		9= other(specify)		
2.1.5	What is the **ESTIMATED** water consumption for each activity daily? (indicate whether in litres or jerry cans)	**category**	**use**	**volume**
		Domestic	Cooking	________
			Drinking	________
			Dish washing	

		Sanitation	Toilet	
			Shower	______
			Clothes washing	______
			Outdoor cleaning	______
		Recreation	Swimming	
			Jacuzzi	______
			bathtub	______
		Agriculture	Irrigation	
			Lawn watering	______
2.1.6	Have you experienced any water leakages?	1=yes	2=no	
2.1.7	If yes, what did you do about it?	1-nothing		
		2-repaired		
		3-other, specify		
2.1.8	When was the last time you had a leakage?	1= today		
		2=one week ago		
		3= two weeks ago		
		4= one month ago		

		5= over a month ago
2.1.9	Do you have any information on water saving strategies?	1=yes 2=no
2.1.10	If yes, above, where did you get the information from?	1= television programme
		2= radio programme
		3= local NGO
		4= newspaper
		5= internet
		6= City council poster
		7= other(specify)
2.1.11	Has your household adapted any water saving strategies?	1=yes 2=no If yes, explain ________________________________ ________________________________ __________________________________ __________________________________ __________________________________

2.1.12	Do you recycle/ re-use any waste water?	1=yes	2=no
2.1.13	If yes in 8 above, how much do you recycle per day? (indicate whether in litres or jerry cans)	A= 1-20 litres	G=<1 jerry cans
		B= 21-60 litres	H=2-3 jerry cans
		C= 61-120 litres	J=4-6
		E= 121-240 litres	K=7-12
		F= Above 241 litres	
2.1.14	How do you use the recycled water (describe the whole recycling process)	____________________ ____________________ ____________________ ____________________	
2.1.15	Do you own a washing machine?	1=yes	2=no
2.1.16	If yes above, how often do you use it?	A= daily B= Weekly C= fortnightly D= monthly E=never F= other(explain)	
2.1.17	Do you own a dish washer	1=yes	2=no

2.1.18	If yes above, how often do you use it?	A= daily B= Weekly C= fortnightly D= monthly E=never F= other(explain)
2.1.19	Do you water your lawn?	1=yes 2=no
2.1.20	If yes above, how often do you water your lawn?	A= daily B= Weekly C= fortnightly D= monthly E=never F= other(explain)
2.1.21	What time of the day do you water your lawn?	A= early morning B= midday C=Late evening D=other (state)

2.2 Activity Profiling

INFORMATION ON BLACK WATER

2.2.1 Is your house self contained? 1=yes 2=no

2.2.2 If yes above, how many toilets do you have?

2.2.3 What kind of flushing system do they have? 1= single 2= dual

3=automated 4=other(specify)

2.2.4 **APPROXIMATELY** how many times in a day is the toilet flushed in your household (cumulatively)?

SECTION 3

3.1 Rainwater Harvesting

3.1.1	Type of roofing material	1=tiles 2=iron sheets 3=asbestos sheets 4= bitumen 5=timber shingles 6= other(specify)	
3.1.2	What is the approximate floor area of your house? (specify the units, whether square meters{ m^2} or square feet {ft^2})		
3.1.3	What is the approximate roof area of your house?(specify the units)		
3.1.4	Do you harvest any rain water for household use?	1-Yes	2- no

If yes in 3.1.4 above:

3.1.5	How much water do you harvest?	Use one: 1-………………………………………..litres 2- …………………………………………jerry cans

3.1.6	How do you store the water?	1=Tank
		2=Cistern
		3=Buckets
		4=other
3.1.7	How do you use the harvested water?	1= cooking
		2=drinking
		3=washing
		4=bathing
		5=toilet flushing
		6=irrigation
		7= other
3.1.8	What limitations have you experienced in harvesting rain water?	

3.1.9 How can these limitations be addressed

If no in 3.1.3 above:

3.1.10 Why don't you harvest rain water ______________________________

____

____

END OF INTERVIEW

APPENDIX 2: MARKET SURVEY

Cost of Plumbing Fixtures

	TYPE OF FIXTURE	MODEL	CAPACITY/ FLOW RATE	COST/UNIT	COMMENTS
1	Toilet cistern				
2	Kitchen faucet				
3	Shower head				
4	Hand wash basin faucet				
5	Other faucet				

APPENDIX 3: RAINFALL DATA

1. DAGORETTI

YEAR	J	F	M	A	M	J	J	A	S	O	N	D
1955	7.4	86.6	31.5	223.8	95.0	1.8	12.7	13.2	45.0	66.3	61.2	173.2
1956	153.2	62.7	89.4	117.3	130.0	3.3	8.6	30.5	21.3	42.2	169.4	23.6
1957	252.7	64.0	81.3	179.1	379.7	41.7	2.0	4.8	58.4	40.1	210.3	67.3
1958	28.4	201.4	73.7	159.3	321.8	41.9	84.8	0.5	9.1	11.9	41.1	89.7
1959	10.9	89.9	189.2	102.4	84.8	2.0	12.7	31.8	62.0	30.5	232.2	34.8
1960	43.7	11.9	207.0	155.4	131.6	37.3	6.4	5.3	24.1	75.7	73.7	53.1
1961	8.4	15.7	75.7	157.0	115.1	24.9	6.9	26.9	35.6	164.1	622.6	379.5
1962	199.1	26.7	23.4	14	255.8	82.3	1.8	42.4	15.7	83.3	104.4	95.2
				5.8								
1963	193.1	58.5	114.0	377.7	253.9	35.9	6.4	51.3	1.9	13.8	202.2	309.5
1964	47.3	85.3	103.7	428.3	112.5	13.5	33.2	67.4	20.8	39.7	88.4	74.8
1965	69.4	4.1	20.4	263.7	91.1	82.4	18.8	10.5	8.7	72.2	158.9	137.7
1966	116.3	49.5	143.9	182.8	168.9	39.9	1.5	77.1	25.6	46.4	113.3	24.6

1967	0.0	17.2	30.9	221.7	477.8	46.0	22.7	46.7	33.5	77.4	93.7	26.8
1968	0.0	172.2	192.7	293.4	127.2	42.1	4.9	3.0	14.4	35.0	284.0	79.3
1969	94.9	77.8	86.7	20.1	196.9	4.0	1.5	28.4	4.3	27.9	102.3	7.9
1970	92.6	12.9	148.4	347.8	224.8	24.2	14.6	4.6	4.5	28.4	113.0	44.2
1971	51.5	6.6	19.4	233.2	322.3	23.1	13.2	9.6	51.3	9.1	66.7	167.3
1972	18.5	76.4	37.2	19.6	228.6	141.3	16.5	4.6	55.7	195.9	125.3	13.0
1973	139.8	97.3	14.9	326.7	61.3	18.4	6.5	4.2	101.8	22.2	68.6	43.6
1974	7.4	9.9	140.4	255.1	49.9	96.6	69.1	9.6	18.2	28.8	98.3	34.9
1975	11.9	1.6	43.7	173.2	188.2	10.4	24.9	2.9	137.6	61.1	100.3	75.8
1976	22.7	42.3	31.0	98.7	85.9	46.3	18.0	18.3	61.1	13.3	177.6	97.4
1977	30.2	75.0	37.5	498.5	312.9	42.4	51.7	50.7	23.5	45.3	268.1	113.5
1978	143.5	34.2	298.9	257.7	36.8	8.5	11.0	64.9	15.4	133.6	125.9	128.9
1979	70.8	165.8	143.6	129.3	184.0	28.5	43.6	10.8	51.4	20.1	107.4	68.8
1980	91.9	13.0	37.9	105.9	418.5	27.2	2.1	17.3	25.2	30.1	250.6	33.5
1981	14.6	6.0	138.7	568.6	232.7	11.3	10.5	38.9	38.7	44.5	18.0	38.0
1982	0.0	19.4	61.7	214.3	217.9	35.9	27.0	8.5	34.1	151.8	220.0	163.7
1983	5.6	182.1	67.6	172.9	39.2	13.1	16.1	29.2	2.8	52.9	24.9	317.9
1984	4.4	1.0	6.3	78.5	3.1	6.3	7.8	7.6	30.6	123.2	140.3	73.6
1985	0.1	92.7	131.9	232.0	72.7	21.6	27.6	5.9	16.1	33.6	111.7	78.3
1986	12.5	0.0	80.1	239.1	259.1	26.2	1.1	3.7	0.2	25.3	192.5	120.8

1987	44.5	11.8	50.7	327.5	94.3	75.7	1.0	10.0	15.1	1.5	157.4	32.1
1988	76.0	25.3	163.8	388.5	241.8	90.6	13.6	30.0	14.8	25.5	82.9	145.8
1989	110.2	47.4	80.2	264.7	257.8	28.3	37.9	23.6	52.4	60.4	114.9	204.6
1990	52.7	27.6	215.8	247.3	219.4	9.7	15.7	8.6	24.8	63.5	140.0	92.9
1991	12.3	0.0	94.0	148.4	253.0	23.2	2.8	40.2	3.9	31.6	182.9	125.8
1992	8.0	73.6	30.2	419.6	94.4	28.3	40.1	5.3	5.6	51.2	134.9	98.4
1993	274.8	151.8	49.1	25.1	95.2	46.6	1.4	11.9	0.0	45.4	101.2	107.6
1994	9.9	92.8	59.1	247.0	114.3	19.8	19.3	53.9	3.4	87.8	245.5	67.7
1995	15.1	116.8	168.2	109.7	210.3	31.3	11.8	25.8	29.2	116.5	95.2	33.2
1996	18.2	45.5	121.4	112.8	89.4	58.3	19.5	28.4	21.9	1.5	167.8	0.0
1997	1.3	0.0	35.0	427.8	13.8	4.9	5.0	15.3	0.5	155.7	383.8	196.1
1998	361.5	144.2	73.9	111.8	412.7	86.4	41.0	25.3	26.0	7.9	56.2	68.9
1999	17.6	0.5	185.0	174.1	25.8	4.4	4.9	61.2	15.9	22.4	286.7	183.7
2000	2.7	0.0	39.5	107.7	120.3	24.1	4.6	9.2	38.6	25.7	174.7	98.0
2001	449.5	31.7	294.5	145	108.9	106.9	25.9	17.6	28.6	38.3	158.7	13.3
2002	43.0	55.4	89.9	205.2	142.1	0.6	22.5	6.4	26.2	75.2	161.5	262.8
2003	52.0	15.7	28.6	232.9	262.9	38.0	2.2	11.3	44.2	70.4	167.4	20.2
2004	133.9	31.7	85.8	322.1	199.2	9.4	0.4	10.1	21.2	72.2	167.9	62.6
2005	102.8	39.2	62.9	162.8	243.2	16.5	16.6	12.1	21.0	45.7	114.4	0.2
2006	8.1	10.8	156.2	307.9	146.7	10.2	4.5	45.1	45.0	36.6	310.1	180.4

2007	28.3	107.3	31.2	199.6	110.0	47.7	46.2	36.7	51.5	38.4	68.9	39.2
2008	45	22.4	133.2	100.3	32.6	3.6	55.1	8.6	89.4	123.8	172.2	0.5
2009	64.5	20.1	37.9	79.3	158.1	101.5	13.2	3.6	9.1	98.4	76.5	121.1
2010	76.0	107.3	252.0	157.3	353.6	37.7	2.5	35.3	28.9	99.2	110.5	65.1
2011	14.2	125.8	128.5	49.4	79.1	125.8	8.7	41.8	31.8	132.6	166.0	129.2
2012	0.0	9.9	5.5	469.1	255.3	26.2	8.6	85.6	9.7	62.8	278.3	268.3
2013	20.2	0.0	176.0	325.1								
mean	67.5	53.8	97.5	217.7	176.1	36.8	17.4	24.0	29.4	59.2	155.9	100.1
stdev	90.3	52.8	71.1	123.1	109.7	32.9	17.9	20.8	25.8	44.3	97.7	84.1
Mean-(61-1990)	57.7	48.5	91.4	242.3	185.0	38.6	17.6	23.9	31.2	57.7	149.1	107.5
Stdev-(61-1990)	83.1	55.7	68.8	135.6	115.3	32.3	16.9	18.0	30.3	51.0	81.5	68.1

2. WILSON

YEAR	J	F	M	A	M	J	J	A	S	O	N	D
1957	251.0	44.4	92.7	180.8	322.4	113.6	3.8	2.0	41.1	38.1	241.6	62.7
1958	78.0	184.6	48.6	112.6	309.6	54.6	68.4	0.3	3.3	6.4	30.5	91.7
1959	22.6	26.6	155.2	100.6	135.5	0.8	7.7	15.4	66.9	11.7	213.8	41.8
1960	108.3	1.5	196.9	135.4	49.1	19.0	6.7	6.6	32.0	58.2	57.5	45.5
1961	2.5	13.0	45.7	116.6	94.2	16.8	3.3	15.0	34.3	142.5	550.7	268.5
1962	181.6	3.1	18.5	154.7	261.6	5.5	0.5	27.7	7.4	67.1	75.2	84.1
1963	74.4	82.1	82.5	347.9	232.4	34.3	14.7	13.6	1.0	5.1	208.0	262.5
1964	46.1	92.1	112.8	296.2	43.4	20.9	21.5	33.9	26.6	40.7	42.2	41.6
1965	110.5	1.2	45.1	280.7	74.6	85.3	17.8	5.2	6.5	65.1	118.6	88.1
1966	62.2	65.8	158.8	134.4	99.7	44.4	0.8	136.8	17.6	29.8	125.9	13.6
1967	0.0	62.0	28.2	239.4	577.1	31.9	17.2	31.9	21.6	94.6	120.8	18.7
1968	0.0	112.3	153.0	324.7	124.5	27.8	1.7	3.1	4.6	37.8	253.3	57.0
1969	81.8	40.4	65.3	19.2	167.7	2.7	1.4	29.3	0.2	30.3	130.2	26.0
1970	110.9	18.4	188.8	220.9	168.2	27.7	6.0	1.3	1.2	51.2	69.0	33.5
1971	64.0	1.2	14.0	285.3	335.7	12.7	8.0	20.6	20.6	17.8	36.6	119.8
1972	9.9	71.2	39.8	10.9	116.7	137.0	24.5	4.1	82.2	204.4	112.7	19.0

1973	183.7	86.0	13.9	249.6	75.0	14.4	4.9	2.8	87.4	15.8	60.9	19.4
1974	15.8	11.5	145.0	248.7	56.0	88.9	53.3	10.2	22.2	22.3	102.9	37.1
1975	5.5	0.8	27.4	134.2	95.5	8.6	12.4	1.0	99.7	64.4	96.5	40.3
1976	3.5	17.5	27.3	112.3	74.2	38.5	13.6	11.7	53.4	18.2	114.1	98.3
1977	22.6	47.9	38.4	450.5	308.7	69.5	34.2	89.4	18.1	26.4	244.4	125.4
1978	140.4	36.1	218.2	221.8	31.3	6.6	7.9	27.4	7.8	66.9	93.9	143.1
1979	35.7	346.2	124.4	112.8	130.6	34.9	28.1	10.6	42.2	27.0	87.8	125.5
1980	90.5	8.6	51.7	105.3	454.1	19.1	1.7	8.8	5.9	18.2	197.2	27.6
1981	3.7	2.0	106.3	323.4	144.9	30.7	9.6	30.4	43.9	41.7	40.2	59.9
1982	2.4	14.1	31.2	192.9	164.4	8.4	13.5	3.1	15.9	186.4	220.1	188.9
1983	1.8	128.0	43.4	137.1	38.0	31.0	22.5	29.8	3.6	63.6	22.4	225.7
1984	7.6	1.6	5.3	87.3	1.6	5.0	12.8	22.4	13.9	144.8	123.9	85.6
1985	0.0	91.2	88.0	188.8	59.7	32.4	50.2	3.1	22.5	20.6	67.5	105.0
1986	17.1	0.0	65.2	284.5	300.1	3.7	0.5	1.6	1.0	22.8	157.3	143.5
1987	40.6	13.6	23.9	278.7	109.0	71.2	15.7	8.4	15.2	1.9	125.3	25.8
1988	78.5	28.4	181.2	322.7	151.1	103.6	7.3	13.1	30.2	9.0	66.7	123.5
1989	95.7	25.1	65.1	277.4	168.3	2.8	59.2	19.5	11.1	45.8	103.5	201.4
1990	46.2	28.8	271.0	171.9	76.1	1.7	3.3	11.1	6.2	34.7	98.4	69.5
1991	28.9	2.4	151.9	114.2	144.2	30.6	2.6	1.0	4.0	28.6	149.6	65.2
1992	1.5	15.1	27.4	414.6	56.8	16.6	88.1	8.7	4.9	37.5	80.1	96.2

1993	272.2	104.0	9.2	9.6	122.9	49.4	0.0	12.8	0.0	49.7	128.1	78.2
1994	12.0	52.4	54.5	172.3	109.9	73.6	10.2	40.0	2.3	69.4	230.9	50.3
1995	39.6	59.6	136.5	80.2	122.3	85.1	18.1	17.8	22.2	118.2	122.3	39.8
1996	6.9	39.6	135.5	95.3	60.1	77.0	13.2	24.0	3.8	5.3	161.5	0.0
1997	0.0	0.0	15.8	324.5	130.7	6.9	7.4	27.9	0.0	102.1	295.3	100.1
1998	436.8	112.2	75.0	84.5	460.2	63.4	62.9	15.2	11.0	0.0	56.6	30.4
1999	3.0	0.0	126.6	156.3	10.6	1.5	4.2	31.9	17.8	33.2	242.3	125.7
2000	9.8	0.0	32.7	85.4	52.7	45.9	3	4.2	23.5	43.9	140.3	78.9
2001	466.3	6.3	283.9	111.5	86.9	66.1	35	16.7	15.9	67.7	211.5	10.1
2002	63.2	13.1	82.2	141.1	117.6	0.0	6.0	3.3	25.6	75.5	109.3	315.4
2003	31.5	4.2	26.6	194.7	364.2	8.5	0.3	60.3	33.7	52.1	106.9	21.2
2004	123.8	62.8	88.2	295.3	79.8	6.0	0.0	0.0	11.1	58.0	117.4	74.1
2005	49.2	14.5	126.5	157.1	285.2	6.6	14.9	5.8	15.8	27.5	73.6	4.7
2006	9.2	42.3	143.2	249.8	89.2	9.2	3.9	29.0	67.5	26.3	293.0	207.7
2007	53.3	104.9	21.6	176.1	60.3	75.4	19.0	21.9	63.5	29.7	87.3	51.0
2008	51.6	24.7	171.4	95.1	19.1	21.4	39.2	6.9	64.7	133.3	248.3	1
2009	59.4	15.3	19.4	83.1	111.5	52	11.4	0	6.9	84.6	91	173.6
2010	65.3	116.6	255.6	82.9	57.6	16.9	1.0	23.9	34.8	117.2	79.0	50.6
2011	10.4	74.8	144.6	46.8	45.4	102.2	10.7	71.0	32.3	145.0	202.3	101
2012	0.0	15.1	3.1	443.3	180.7	33.1	30.0	35.3	19.3	60.7	219.2	234.2

2013	26.2	0.0	143.5	264.8								
mean	66.9	45.4	92.1	188.4	148.6	36.7	16.7	19.8	24.1	55.3	140.3	89.8
Stdev	95.5	58.3	71.9	106.3	122.5	33.7	19.4	23.7	23.9	46.3	90.1	74.4
Mean-(61-1990)	51.2	48.3	82.6	211.0	157.8	33.9	15.6	20.9	24.1	53.9	128.9	95.9
Stdev-(61-1990)	94.9	68.2	67.6	112.1	118.2	35.6	21.9	17.3	26.3	51.6	67.9	56.8

3. J.K.I.A

YEAR	J	F	M	A	M	J	J	A	S	O	N	D
1958	106.8	193.1	66.3	58.2	0.0	26.9	4.8	27.7	86.6	124.5	59.4	95.5
1959	21.9	17.0	178.3	68.4	134.6	0.0	13.5	28.9	0.8	29.7	156.8	58.9
1960	73.1	10.7	133.6	88.9	48.8	10.3	18.8	0.6	33.2	47.9	96.5	29.7
1961	0.8	11.9	98.8	73.2	108.2	30.8	5.2	10.5	33.1	159.4	484.0	276.0
1962	112.2	6.9	7.0	118.8	193.6	39.3	1.6	6.6	7.1	69.4	131.2	120.4
1963	100.8	86.4	128.6	226.3	188.2	32.0	0.0	39.6	0.8	13.6	264.0	204.9

1964	55.7	50.6	31.3	176.1	32.0	31.9	9.0	24.0	26.7	16.3	52.9	65.9
1965	44.6	2.0	29.6	210.9	16.5	14.6	14.4	1.9	4.1	52.5	77.4	20.1
1966	24.9	90.9	114.2	97.4	48.5	15.1	0.0	35.1	8.0	28.2	92.7	16.3
1967	0.5	34.6	37.8	214.2	372.5	37.4	8.4	32.1	9.3	66.6	86.4	40.3
1968	0.0	141.0	138.3	251.4	61.9	20.7	1.9	1.9	0.0	34.5	278.6	54.6
1969	76.6	41.0	41.8	8.7	138.2	2.4	0.6	13.5	1.4	27.9	111.3	13.6
1970	126.0	3.2	111.4	190.1	93.5	9.7	10.3	1.4	0.6	32.1	34.0	23.1
1971	33.9	1.6	5.1	270.6	165.0	12.0	8.1	38.1	11.7	2.6	26.5	163.2
1972	11.9	53.1	28.0	0.7	80.1	120.6	8.6	2.4	54.7	161.5	97.4	24.8
1973	106.1	33.7	1.4	54.5	61.4	21.8	0.9	3.0	62.7	14.5	80.3	18.8
1974	25.3	60.7	136.6	201.4	86.6	48.1	43.6	18.6	32.9	10.9	70.9	71.0
1975	9.4	0.1	31.4	123.8	90.7	11.4	25.0	0.2	78.0	31.1	92.4	37.1
1976	2.8	24.5	50.5	132.6	33.1	21.0	28.5	4.1	40.4	4.6	111.1	96.8
1977	12.9	50.3	30.8	348.4	144.2	17.9	19.2	51.7	12.8	16.9	231.1	75.2
1978	76.8	57.7	202.9	128.1	36.1	3.1	20.8	3.9	6.9	24.3	126.6	118.8
1979	78.4	288.5	67.9	99.9	94.0	17.4	14.4	5.2	0.7	6.3	80.4	34.6
1980	56.7	10.6	78.0	93.9	307.0	16.5	0.0	14.4	0.3	25.0	6.4	101.9
1981	2.0	0.8	80.5	196.7	185.2	0.0	3.5	3.4	21.1	30.7	32.8	51.6
1982	1.8	4.6	11.6	120.5	91.4	8.1	8.1	13.3	17.9	147.8	149.4	113.1
1983	1.0	160.3	38.7	208.3	29.2	68.8	6.2	17.4	0.9	29.2	31.8	195.9

1984	7.8	0.0	17.6	64.7	3.4	0.7	6.4	5.5	117.6	134.1	104.5	203.7
1985	12.3	141.2	59.3	189.5	54.3	16.7	8.2	1.3	17.0	35.1	46.1	118.9
1986	34.7	0.0	112.1	245.2	167.8	11.1	0.1	2.2	1.5	3.0	140.4	90.1
1987	21.5	8.5	7.0	120.0	92.8	78.6	0.6	16.5	9.0	0.0	63.6	21.6
1988	1.6	146.7	223.6	52.5	23.0	5.0	4.4	20.5	46.2	57.4	87.5	422.8
1989	108.3	30.2	70.8	217.7	192.3	0.8	34.3	16.3	59.3	105.4	165.0	226.0
1990	27.1	34.9	178.9	167.2	54.9	3.2	5.3	56.0	17.6	60.6	168.8	94.7
1991	9.6	6.0	98.5	54.7	209.3	15.6	1.8	6.9	2.4	35.2	84.6	95.9
1992	3.4	10.2	8.7	227.3	155.0	12.7	35.7	9.7	0.4	37.7	78.5	132.6
1993	210.9	51.7	17.0	8.3	51.4	43.2	0.0	4.1	0.0	69.7	68.6	83.2
1994	0.6	97.2	47.6	163.0	58.0	35.7	3.1	23.7	0.0	73.1	203.4	34.5
1995	59.1	79.4	133.3	70.7	86.4	46.9	18.1	17.5	32.3	45.6	29.5	32.4
1996	36.9	69.4	55.8	61.2	55.8	58.6	16.3	12.1	2.0	0.0	129.0	10.6
1997	0.0	0.0	35.0	235.6	163.1	8.6	14.7	22.4	0.0	80.4	307.7	184.6
1998	293.7	111.1	53.1	110.4	326.7	69.9	1.0	6.2	18.1	0.0	68.7	6.4
1999	0.9	1.3	123.5	88.6	3.0	1.9	3.8	33.2	0.0	37.9	251.1	95.9
2000	13.4	0.0	18.5	74.8	18.7	26.9	1.0	1.4	8.0	11.6	113.4	37.4
2001	275.4	10.7	122.1	67.8	38.6	13.7	19.9	14.3	3.7	33.6	197.7	15.9
2002	57.6	15.1	99.1	151.9	158.9	1.6	0.2	3.9	54.5	48.7	115.1	331.2
2003	16.9	9.5	22.1	154.6	234.8	6.8	1.6	47.8	17.8	52.3	119.8	24.3

2004	95.3	76.2	93.3	137.6	57.9	10.7	0.0	0.6	26.5	65.3	123.5	81.4
2005	36.7	1.4	46.3	130.2	89.5	3.6		3.4	9.1	6.6	65.5	1.2
2006	6.3	38.0	124.5	222.9	98.6	0.2	0.0	27.8	5.5	19.2	232.6	204.2
2007	83.4	18.2	35.8	195.7	52.8	27.2	28.0	12.0	19.6	23.7	95.0	36.4
2008	40.5	2.8	134.6	81	4.7	0.5	27.2	3.2	32.2	100	82.6	0.1
2009	52.4	1.9	27.1	84.5	140.0	33.7	5	0.6	2.3	60.4	45.5	112.5
2010	54.0	71.2	133.1	37.2	73.0	23.1	1.3	6.6	8.0	34.9	77.9	55.7
2011	1.8	53.6	91.1	17.8	45.0	29.6	2.9	42.2	27.8	47.4	249.6	29.1
2012	0.0	3.4	4.2	281.7	195.6	32.2	13.4	4.1	36.8	60.9	58.6	194.5
2013	34.7	1.4	134.2	237.4								
mean	49.3	45.1	75.1	137.7	104.5	22.9	9.8	14.9	20.5	46.3	120.7	92.7
Stdev	62.6	57.8	55.6	79.5	82.9	23.1	10.7	14.6	25.0	40.2	86.0	87.2
Mean-(61-1990)	42.0	51.1	72.4	153.4	108.2	23.9	9.9	15.4	23.3	46.7	117.5	103.9
Stdev-(61-1990)	65.9	65.4	60.5	81.0	85.2	26.4	11.0	15.6	28.0	47.7	95.8	93.0

4. MOI AIRBASE

YEAR	J	F	M	A	M	J	J	A	S	O	N	D
1967	0.0	1.8	39.4	180.4	542.5	42.7	15.2	43.0	22.3	98.9	70.5	23.1
1968	0.0	209.9	280.3	278.0	61.7	60.2	2.1	3.0	1.8	59.3	250.9	74.8
1969	62.6	62.5	49.0	24.6	170.6	5.8	1.4	27.6	0.0	20.0	156.2	17.6
1970	113.8	70.0	192.9	156.8	101.2	39.3	1.9	5.3	0.0	40.0	89.1	34.7
1971	84.4	0.0	21.5	261.2	305.3	16.9	21.0	47.0	14.8	15.0	50.2	106.6
1972	11.2	54.3	39.8	14.8	121.2	156.8	7.1	5.4	35.9	152.0	128.7	17.6
1973	96.3	82.2	11.0	126.2	69.6	15.3	5.8	5.2	35.8	12.5	62.9	18.1
1974	5.2	8.4	105.6	320.3	38.4	66.6	70.4	22.1	15.8	27.0	99.2	43.8
1975	7.5	3.9	26.4	42.1	81.6	8.3	36.5	0.4	82.2	48.1	130.8	32.9
1976	6.1	31.5	25.2	9.1	18.5	19.1	10.4	4.4	55.9	9.6	86.6	94.9
1977	15.5	65.1	32.2	341.0	322.9	81.0	31.1	95.6	9.4	36.8	233.8	98.2
1978	148.4	79.7	177.7	217.9	28.0	5.7	12.3	22.2	3.6	86.8	117.9	132.5
1979	105.7	157.1	97.9	116.1	147.0	21.6	12.3	3.9	6.0	16.5	190.9	18.0
1980	96.0	8.6	51.4	100.1	339.2	53.9	0.6	15.4	3.4	28.6	238.9	16.3
1981	5.8	2.4	115.1	277.9	316.0	2.0	7.7	20.2	75.5	58.1	38.4	69.9
1982	3.5	15.0	33.0	173.6	162.4	54.9	8.8	3.5	13.7	178.2	201.6	145.5

1983	0.3	150.2	68.3	239.1	33.6	53.6	38.3	42.3	1.9	67.9	23.5	245.6
1984	17.8	2.9	6.8	45.5	0.0	1.8	10.5	16.5	18.6	154.7	210.2	95.9
1985	0.3	77.0	77.3	180.5	53.9	12.8	43.4	1.7	29.1	32.1	57.6	106.9
1986	20.4	0.0	69.8	348.3	334.8	22.5	1.8	0.5	13.9	34.9	174.3	125.3
1987	38.0	16.6	17.1	219.1	92.6	41.0	39.8	22.6	8.2	0.0	98.8	26.5
1988	91.5	9.8	166.7	391.3	104.2	71.5	5.7	9.7	42.8	24.8	98.1	128.5
1989	114.1	22.6	101.5	164.1	145.5	7.4	40.2	35.0	29.5	52.7	108.0	206.6
1990	66.6	33.1	216.9	199.8	104.2	20.2	5.0	44.1	21.2	57.3	148.4	120.2
1991	34.9	5.7	176.0	119.3	151.6	29.6	7.6	38.0	3.4	28.1	152.8	75.2
1992	9.1	0.0	16.3	262.3	61.7	23.5	27.2	22.8	6.0	80.2	87.5	87.0
1993	268.1	77.8	15.8	27.4	79.5	52.9	1.6	22.7	0.0	21.6	97.9	84.7
1994	9.3	81.4	44.5	212.9	65.1	44.4	15.2	26.4	0.0	111.1	281.0	67.1
1995	52.6	62.4	162.5	110.0	61.8	58.1	7.2	21.8	7.6	55.1	84.6	55.8
1996	5.8	62.7	139.8	160.4	67.4	64.8	13.5	35.2	26.1	0.0	185.2	2.7
1997	0.0	0.0	20.8	314.9	128.9	45.5	32.8	33.2	0.0	69.1	308.6	134.9
1998	375.1	225.5	59.8	110.2	472.8	107.5	13.7	16.9	50.7	16.6	57.1	6.4
1999	1.6	2.4	128.8	126.4	4.5	3.4	10.2	21.8	30.7	24.2	204.1	130.3
2000	1.1	0.0	28.4	71.1	49.7	36.7	1.1	2.3	15.7	36.0	140.4	82.2
2001	403.4	5.2	215.0	104.7	97.2	31.4	19.9	20.1	7.0	36.8	220.9	8.6
2002	55.5	43.6	91.5	220.0	293.9	0.0	4.2	8.4	29.3	90.1	97.5	210.0

2003	22.0	8.9	20.4	112.0	268.2	3.2	3.1	29.8	6.9	82.7	104.5	23.9
2004	51.9	64.4	102.9	298.7	102.0	3.8	0.0	2.0	11.2	68.6	88.3	77.2
2005	35.9	15.9	58.8	158.4	239.7	11.6	11.1	16.7	17.4	17.5	87.1	1.5
2006	8.2	65.5	133.0	274.7	122.8	3.6	6.0	21.5	29.3	37.6	308.3	223.2
2007	40.7	64.3	20.1	194.1	84.4	85.9	46.4	35.5	25.7	35.4	98.7	85.1
2008	58.8	24.7	168.9	103.9	7.3	2.1	28.1	3.7	15.4	109.1	128.1	0.2
2009	52.3	21.2	19.3	163.7	144.3	32.3	8.5	1.3	7.6	61.2	41.7	139
2010	105.8	80.8	377.4	109.9	157.8	63.7	0.5	10.4	24.1	67.4	119.8	74.9
2011	15.0	43.8	80.5	32.5	91.6	28.1	10.1	16.1	47.0	90.4	225.4	75.7
2012	0.0	16.4	6.1	341.0	311.6	101.0	3.9	35.2	36.5	42.0	127.5	161.2
2013	36.4	1.1	191.0	293.8								
Mean	58.6	45.5	91.5	177.7	146.9	37.3	15.2	20.4	20.4	54.2	137.2	82.8
Stdev	87.3	52.8	81.2	100.9	124.6	33.4	15.6	17.7	19.3	40.4	72.6	62.5
Mean-(71-2000)	56.4	44.6	75.1	176.8	132.1	40.0	18.0	22.0	21.9	51.2	136.6	85.9
Stdev-(71-2000)	84.8	55.3	60.5	106.1	120.6	34.5	16.6	19.7	21.7	45.7	72.9	58.0