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Presented by

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TITLE: ANALYSIS OF RAIN WATER QUALITY FOR WATER SUPPLY: A CASE STUDY OF KIBOGA DISTRICT IN CENTRAL UGANDA

Defended on 26/09/2018 Before the Following Committee:

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DECLARATION

I Micheal MUTAMBO, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

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APPROVAL

This project proposal has been submitted for examination with my approval as the university supervisors

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DEDICATION

I dedicate this work to my family, and people practicing rainwater harvesting in the entire world.

ABSTRACT

Water shortage is a big challenge in most of the developing countries. Water scarcity problems are mainly faced by Arid and semi-arid regions. Based on precipitation intensity data of many places across the globe, it is evident that rainwater is a potential solution to water scarcity. The thesis investigated the quality of rainwater harvested for water supply in Uganda, and suggests policy recommendation for this cheap and effective source of water supply for developing economies.

A questionnaire was used to understand the public's perception about rain water quality, regulation, practice and perceived risks of contamination. Samples of direct rain, roof runoff and surface runoff were collected for two months and taken to the laboratory for a selected physical, chemical and biological analysis.

The laboratory analytical results show that surface runoff is highly contaminated as compared to roof runoff and direct rain respectively, direct rain and roof runoff have a slightly acidic pH as compared to average pH of 6.8 recorded in surface runoff. Generally all samples exhibited low concentrations of heavy metals. There was zero detection of fecal coliforms in direct rain and 100% detection of fecal coliforms in both roof and surface runoff samples.

In order to have rainwater of good quality that can be put to use for different purposes, possible risks/sources of contamination should be identified and prevented and an appropriate treatment method should be used.

Key words*, Rainwater, Harvesting, Quality and Treatment.*

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LIST OF ACRONYMS & ABBREVIATIONS

E.Coli)	Escherichia coli
e.g.	For example
et al.,	et alie (and others)
Fe2+	Total Iron
Fig.	Figure
MWE	Ministry of Water and Environment
ND	Not Detected
NO_{-3}	Nitrate
Pb	Lead
pH	Potentia hydrogenii
RWH	Rainwater harvesting
TDS	Total Dissolved solids
TOC	Total Organic Carbon
WHO	World Health Organization
Zn	Zinc

CHAPTER ONE: GENERAL INTRODUCTION

1.0 Background

Access to safe and affordable drinking water is a fundamental human need and therefore, a basic right (UN Human Rights Council, 2010). Access to safe water is not only vital for good health but also for satisfactory livelihoods, dignity and prospects for economic growth and education. Unsafe drinking water and poor sanitation impact health by causing water-related diseases (diarrhoeal diseases, schistosomiasis, filariasis, trachoma, and helminthes).

Recently, RWH systems have been widely identified as a solution to the growing water scarcity and a measure of adaptation to climate change impacts on water resources. Indeed, having another form of water source can lower the pressure on ground and surface water. Harvesting rainfall also has important economic advantages because they lower the need to purchase water from the conventional systems (Oweis and Taimeh, 1996). For these reasons some researchers have studied the role of rainwater harvesting in addressing the increasing global water demand. These studies have been carried out in the Mediterranean regions, Greece, Italy, and Spain (Vincenza Notaro *et al*, 2016***)***.

Rainwater harvesting (RWH) to supply water for domestic purposes is a common practice in developing countries, especially in arid and semi-arid areas affected by water scarcity (Oweis and Taimeh, 1996, Pachpute *et al*., 2009, Kahinda, 2007), but also in urban areas (Vincenza Notaro *et al*, 2016***).***

The concepts of Rainwater harvesting have predominantly been embraced by the semi-arid regions, these areas use decentralized technics which include Valley tanks, ponds, dams, deep tillage and small reservoirs to mitigate droughts and water scarcity (Akpinar Ferrand & Cecunjanin, 2014).

Rainwater harvesting for supplemental irrigation in dry seasons is successfully being practiced in some semi-arid and arid areas (Richardson et al., 2004; Qiang et al., 2006; Short and Lantzke, 2006; Arya and Yadav, 2006).

Dry lands cover 44% of Uganda. Uganda's dry lands are hit most with climatic variability in the form of droughts and floods with their devastating effects. Entitlement to clean and safe water is enshrined in the Ugandan constitution and in a bid to tackle the water scarcity problem, the Government of the republic of Uganda and several development partners have undertaken a number of rain water harvesting development projects for these dry lands, these include; construction of multi-purposes dams, valley tanks and ponds (Mugerwa, *et al*, 2014). According to the ministry of water and environment performance report, 2016, the Cumulative bulk rain water Storage Capacity is 38.865 Million Cubic Meters in the country.

Two-thirds of Uganda receives rainfall in excess of 1200 mm per year, which is primarily bimodal in nature, with the heaviest rains from April to November (Danert and Motts, 2009).
Most parts of the country experience a bimodal rainfall pattern and is characterized as a humid tropical environment. The first rain season occurs during March, April and May (MAM) and the second rain season occurs during September, October and November (SON). The first dry season is from June, July and August (JJA) while the second one occurs from December, January and February (DJF). April,
October and November are normally the wettest months of the year while February and July are normally the driest months of the year. Annual rainfall ranges from less than 1000 to 2000 mm and is greatly influenced by altitude.

1.1 Problem Statement

Water scarcity is one of the biggest problems faced by many societies worldwide, it's a threat to life and development and it requires an immediate solution with an increasing population worldwide (UNDESA, 2015).

The world's fresh water supplies (Lakes, rivers, and ground water) are decreasing as result of climate change phenomenon (Betasolo and Smith, 2016). This could be a hindrance to development in the affected countries (Sekar & Randhir, 2007).

OECD, 2012 predicts that with the current economic growth rate, the demand for water will continue to increase worldwide since water is a factor of production and a prerequisite for life. According to UNEP, 2014, the world's water demand is expected to exceed supply by 40% within 20 years, and WBCSD, 2014, projects 60% increase in food demand by 2050.

Water Resources are experiencing increased pressures from urban development, Irrigation and livestock watering and impacts of climate change. It is estimated that between 75 to 250 million people in Africa will suffer economic and physical water stress by 2020, climate change will affect rain fed agriculture by about 50% yield reduction in some regions, this will brutally comprise access to food (Field etal.,2014).

Water scarcity problems are mainly faced by Arid and semi-arid regions, these dry lands represent about 35% of the earth's land (Ziadat etal, 2012). Farmers in these regions experience low average annual rainfall and variable temporal and spatial rainfall distribution. In order to ensure water availability for different purposes, some dry land dwellers have employed a number of rainwater harvesting technologies. The common RWH techniques include; Ponds and pans, Valley dams, terracing, percolation tanks, and Nala (Oweis, Prinz, & Hachum, 2012).

Uganda's dry lands commonly referred to as the "Cattle corridor" cover about 40% of the country's area. According to a report by FAO, Uganda, 2017, 60% of the people in these areas do not have enough water for domestic consumption, crop production and livestock watering. In awake to address water scarcity in these areas, donor agencies and the ministry of water and environment-Uganda through their department of water for production has implemented a number of rainwater harvesting projects in these areas. According to the ministry of water and environment performance report, 2016, the annual Cumulative bulk rain water Storage Capacity is 38.865 Million Cubic Meters in the country, this water is mainly used for livestock watering and small scale irrigation but it is also used for domestic purposes mainly during dry seasons.

Despite the rising increase of rainwater harvesting in these areas and Uganda at large, the quality of Rainwater is never attended to by the public and policy makers' yet harvested rainwater might be contaminated during collection and storage by bacteria, heavy metals and harmful chemicals and therefore may require treatment before usage. Most rainwater users in the country seem not to have sufficient knowledge of water quality, water quality safeguard measures, treatment, and water-related illness. And most funding agencies do not pay attention to water quality for instance; it is common for funding agencies to subsidize tank-building or supply plastic tanks and leave gutters and first flush divert systems to the householder's discretion. 100% of the excavated ponds for water storage by these agencies do not have any water quality measures in place.

Using water of unknown quality from such systems is a threat to health since water is not only a precious resource, and a prerequisite for life, but it is also an element for transmitting disease (Andreas T, 2015). The uncertainty of the quality increases the risk of disease and slow progress towards exploiting the potential benefits and opportunities of rain water harvesting.

Therefore, while the use of harvested rainwater can contribute to increasing the available water, it might at the same time introduce new health threats due to waterborne diseases (Leder et al. 2002). Thus, attending to the quality of collected rainwater is inevitable.

1.3 General objective

To assess the quality of harvested rainwater for water supply

1.3.1 Specific objectives

1. To analyze public perceptions of Rainwater quality, use and perceived risks of contaminants of rainwater.
2. To investigate rainwater quality at different stages of rainfall events.
3. To review and propose possible treatment methods and best practices that improve rainwater quality.

1.4 Research Questions

1. What are the public perceptions of Rainwater quality, use and perceived risks of contaminants of rainwater?
2. What is the rainwater quality at different stages of rainfall events?
3. What are the possible low cost treatment methods and best practices that improve rainwater quality?

1.5 Significance of the study

The findings of this study present the rainwater quality state, Rainwater harvesting practice, public perception about rain water quality, Rainwater quality threats and proposed rainwater quality guidelines and treatment.

1.6 Scope of the study

There are several potential rainwater catchment points in the environment, and each catchment point involves a specific pollution, representing advantageous and disadvantageous potentials for each one of the water's intended uses. This means that within the rainwater cycle a downstream collection point will supposedly gather a higher volume of rainwater but with poorer quality due to the incorporation of pollutants, first of all, from the roof runoff, subsequently from the surface runoff and, finally, from contact with wastewater. This will definitively restrict use and increase the need for specific management in terms of collection, treatment, and storage.

This study therefore looked at a rain water cycle which comprised of all points through which rainwater flows before returning to the receiving environment or wastewater treatment plants. For purposes of clear discussion of the results, these points were grouped into 2 main categories depending on the expected harvested rainwater quality. The first category comprised of points that involved the collection of fairly better quality of rainwater (pure rain and roof runoff). The second category comprised of medium rainwater quality (surface runoff harvested in ponds or valley tanks).

Roof runoff points were located within the case study, which represents a typical rural farm area with no industrial activity. Roof materials were mainly iron sheets this is due to the fact that most houses in the study areas were roofed with Iron sheets, Surface runoff samples were obtained from two valley tanks in the study area.

People in the study area were interviewed through a questionnaire to obtain information pertaining, Rainwater quality, use, treatment, regulation and perceived contamination sources.

CHAPTER TWO LITERATURE REVIEW

2.1 Introduction

The study focused on the quality of harvested rain water for different uses. Harvested Rain water is used for different purposes which include, Irrigation to improve crop production, Livestock watering, domestic water supply and small scale industrial use. Water quality requirements and the potential uses are key aspects of any rainwater application. The quality standards vary depending on the potential uses of water. Therefore a specific water resource requires a specific level of treatment, depending on the potential use. This makes it important to investigate the initial water quality of each resource, in order to assess the potential uses, level of treatment, appropriate storage and distribution system.

Literature in regard to the topic was obtained from mainly from journals and reports (both international and National reports) and reviewed.

2.2 Rainwater harvesting techniques

Precipitation is one of the hydrological cycle processes. Unlike the other water sources, rain in the form of direct precipitation, runoff, infiltration and percolation feeds rivers, lakes, and ground water aquifers (Kaposztasova *et al*., 2014).

Rainwater can be regarded as a main water resource for the future because of its fairly good quality. The Texas Water Development board, 2005 considers every raindrop to be very soft and cleanest water source in this world.

Rainwater is an important source of fresh water especially for those who live in rural areas, where water use is limited due to scarcity or where surface and underground water quality is poor. In many areas, rainwater is still considered as a safe and suitable source of potable water, and it is commonly used as such (Vikaskumaret al., 2007).

In rural areas and other areas where there is water scarcity or where the quality of groundwater and surface is poor, Rainwater can be the solution (Bidisha, 2015). Rainwater is considered to be safe and a suitable source of potable water in many parts of the world (Vikaskumaret)

Rainwater can be collected from different hard surfaces which include rocks, concrete surfaces, roof tops, courtyards, asphalt surfaces and other well prepared or treated surfaces. The collected rain which hits the ground is referred to as storm water. In most cases the harvested rain is used in the closet place it falls (Lancaster, 2013).

The system of rainwater harvesting starts by having a catchment area where rain falls, followed by a collection point/ storage, this can be a water tank, a pond, dam among others, and lastly conveyance system to a point of use. The rain water collected from different surfaces may be treated mainly by filtration before storage and use (Notaro et *al.*, 2016). This rain can be used for different purposes which could be domestic and agricultural. It can be noted that one millimeter of harvested rain per square meter is equivalent to one liter of water.

(Helmreich & Horn, 2008) classifies rainwater harvesting in three forms; a) In situ RWH where rain water is collected on surface where it falls and stored in soil. b) External RWH here runoff coming from elsewhere is collected and stored offsite for use. c) Domestic RWH, in this form rain from roof tops and paved compounds is collected and stored for use.

2.3 Agricultural RWH

The use of RWH to irrigate rain fed crops may increase water productivity and in turn increase crop yield. Commonly arid and semi-arid regions practice Rain fed agriculture which contributes to about 90% of cereals produced in these areas (Kahinda, *et al,* 2005). However, the productivity in these areas remains low due to mainly erratic rainfall and other factors like unfavorable land and poor farming practices. Promoting RHW agriculture in these areas will increase productivity of rain fed agriculture in these areas thus ensuring food security, improving livelihoods and reducing Irrigation rate. RWH agriculture largely depends on climate but also the land scape plays a big role. Apart from the climate, the landscape must be suited for RWH agriculture. UNESCO, 2008 provides minimal requirements to be fulfilled for RWH agriculture:

• The landscape surface must be such that runoff is readily generated by rainfall.

• Differences in elevation must be present in the landscape surface. The runoff generated by rainfall must be allowed to flow and to be concentrated in the specially prepared parts of the landscape.

• The runoff receiving part must have sufficiently deep soils of suitable texture and structure to retain and store the received runoff water.

Surface and Sub Surface storage systems may be employed to store Rainwater. Any of the storage method may be applied depending on one's financial strength. There are various systems of Runoff collection as explained below (Falkenmark, et al, 2001).

a) Micro-catchment systems: They constitute specially contoured areas with slopes and berms designed to increase runoff from rain and concentrate it in a planting basin where it infiltrates the soil profile and is effectively ''stored'' therein. The water is available for plants but protected from evaporation. Micro catchments are simple and inexpensive and can be rapidly installed using local materials and manpower.

There are three types of micro-catchments: contour bench terraces, runoff strips, and micro-watersheds.

b) Sub-surface dams, sand dams or check dams: Water is stored underground in an artificially raised water table or local sub-surface reservoir.

c) Tanks of various forms made of plastic, cement, clay, soil, etc: They can be built underground or above ground, depending on space, technology and investment capacity.

2.4 Domestic rainwater harvesting

DRWH is commonly collected from rooftops but it can also be collected from courtyards and streets. The collected water is stored in tanks, these can be underground or above the ground. The stored water is put to different domestic uses, small scale production and garden watering. The tank dimensions vary depending on the need. Tanks are in different shapes; cuboid, cylindrical or doubly curved. Tanks made of bricks, metallic material; plastic, stabilized soils and rammed earth can be used to store low water quantities. Large water quantities can be stored in tanks made of Ferro cement, polyethene and earth excavations (Kahinda, *et al*, 2007)

It is best practice for rainwater storage tanks to have provisions of an adequate enclosure to limit contamination from human, and any other contaminants from the environment. They should as well have a tight cover to prevent algal growth and breeding of mosquitoes.

The main advantage of DRWH is to provide water right near the household, lowering the long distance walks burden of water collecting (Kahinda, *et al*, 2007).

2.5 Description of rainwater quality parameters

Colour

Colour in water is usually due to organic matter in colloidal condition but sometimes it is also due to mineral and dissolved organic impurities.

The colour produced by one milligram of platinum in a litre of water has been fixed as the unit of colour.

The permissible colour for domestic water is 20 ppm on platinum cobalt scale.

The colour in water is not harmful but objectionable

Turbidity

Turbidity is a measure of resistance of water to the passage of light through it.

Turbidity is expressed as NTU (Nephelometric Turbidity Units) or ppm (parts per million) or mmilligrams per litre (mg/I).

Turbidity is due to presence of suspended and colloidal matter in the water such as clay,silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms.

Drinking water should not have turbidity more than 10 NTU.

Turbidity test is useful in determining the treatment level required and the dosage of coagulants to remove or reduce turbidity to permissible level.

pH

The pH denotes the concentration (activity) of hydrogen ions in the water and is used to measure the acidity or basicity of a solution. Depending upon the nature of dissolved salts and minerals, the pH value ranges from 0 to 14. For pure water, pH is 7; pH is 0 to 7 acidic and 7 to 14 in the alkaline range. For public water supply pH may be 6.5 to 8.5. The lower value may cause tuberculation and corrosion, while as higher values may produce incrustation, sediment deposits and other bad effects.

The cations and anions are used to determine the ionic chemical composition of water and to assess its suitability for different uses.

Alkalinity of water is the capacity of water to neutrlise acids, and Acidity measures the amount of basic substance to neutralise water.

Zinc

Zinc (Zn) is the first element in group IIB in the periodic table; it has an atomic number of 30, an atomic weight of 65.38, and a valence of 2. The average abundance of Zn in the earth's crust is 76ppm, in soils it is 25 to68ppm, in streams it is 20microns/l and in ground water it is less than 0.1mg/l. The solubility of Zinc is controlled in natural waters by adsorption on mineral surfaces, carbonate equilibrium, and organic complexes. Zinc is used in a number of alloys such as brass and bronze, and in batteries, fungicides, and pigments. Zinc is an essential growth element for plants and animals but at elevated levels it is toxic to some species of aquatic life. The United Nations Food and Agricultural Organization recommended level for zinc in Irrigated waters is 2mg/l. The U.S EPA secondary drinking water standard MCL is 5mg/l. Concentrations above 5mg/l can cause a bitter astringent taste and opalescence in alkaline waters. Zinc mostly commonly enters the domestic water supply from deterioration of galvanized Iron sheets and dezincification of brass. In such cases, lead and cadmium also may be present because they are impurities of the zinc used in galvanizing. Zinc in water may also result from industrial waste pollution.

Lead

Lead (Pb) is the fifth element in group IVA in the periodic table. It has an atomic number of 82, an atomic weight of 207.19 and valences of 2 and 4. The average abundance of Pb in the earth's crust is 13ppm; in soils it ranges from 2.6 to 25ppm; in the streams it is 3micron/, and in ground water it is generally less than o.1mg/l. lead is obtained chiefly from galena (PbS). It is used in the batteries, ammunition, solder, piping, pigments, and insecticide, and alloys. Lead in water supply my come from industrial, mine, and smelter discharges or from the dissolution of plumbing and plumbing fixtures. Tap waters that are inherently noncorrosive or not suitably treated may contain lead resulting from an attack on lead service pipes, lead interior plumbing, brass fixtures and fittings, or solder pipe joints.

Iron

Iron (Fe) is the first element in group VIII of the periodic table, it has an atomic number of 26, an atomic weight of 55.85, and common valences of 2 and 3 and occasionally valences of 1, 4, & 6. The average abundance of Fe in the earth's crust is 6.22%, in soils it ranges from 0.5 to 4.3%, in streams it averages about 0.7mg/l and in ground water it is 0.1 to10 mg/L. Iron is widely used in steel and other alloys.

Elevated iron levels in water can cause stains in plumbing, laundry, and cooking utensils, and can impart objectionable tastes and colors to foods. The United nations food and Agricultural organisation recommended level for irrigation water is 5mg/l. The USESPA secondary drinking water standard MCLis 0.3 mg/L.

COD

The COD is used as a measure of the oxygen equivalent of the organic matter content of sample that is susceptible to oxidation by strong chemical oxidant. Oxidation of most organic compounds is 95 – 100% of the theoretical value.

2.6 Quality of harvested rainwater

Often time's pure rainwater is less polluted depending on the quality of the atmosphere and indeed rain is the purest form of water before being contaminated by pollutants in the atmosphere.

Rain formation is as a result of condensation of the water vapor in the atmosphere that is pulled down under the action of gravitation forces into water drops heavy enough to fall and be deposited on the earth's surface (Robert, 2002). Not all rain reaches the earth's surface,some evaporates when it falls in dry lands. Rainwater collects minor constitutes of the atmosphere, therefore rainwater analysis results can be of help in revealing the chemical state in which the rain was formed. The precipitation process is a powerful mechanism in which pollutants are removed from the atmosphere (Bidisha, 2015).

Atmospheric contaminants which include; particles, heavy metals, organic substances and microorganisms over time accumulate on catchment surfaces and are washed out from the atmosphere during precipitation events. Rain water in rural areas is clean except commination from dissolved gases. This is as a result of having low or no industries situated in these areas thus low industrial pollution. On the other hand urban areas are characterized by a high traffic and industry impact and are therefore contaminated by particles, heavy metals and organic air pollutants.

Catchment surfaces themselves can be a source of pollutants mainly heavy metals and organic substances. For example rainwater collected from roofs constructed with tiles, slates and aluminum sheets is less or not polluted (Gould, 1992). On the other hand rainwater collected from roof tied with bamboo gutters, zinc and copper roofs and roofs with metallic paint or other coatings are least suitable because of possible health hazards like high levels of heavy metal concentrations.

Rainwater collected from industrial sites is susceptible to pollution from heavy metals originating from brakes and tires and organic compounds from incomplete combustion.

Rainwater is contaminated with heavy metals, the major heavy metal linked to rainwater pollution include; Cr, Zn, Cu, Hg, Pb, Cd, and Ni. The presence of these metals in rainwater is mostly as a result of anthropogenic activities like industrial processes specifically mining, processing metal ores and manufacturing metal objects (Hernandez et al., 1990).

Metals are natural components of the earth's crust. Natural metal sources include volcanic eruptions and dusty storms, and anthropogenic sources include Vehicular exhausts, fossil fuels combustion, and metal refining. Metals remain in the atmosphere until removed by rain wash or by dry deposition. (Hou et al., 2005). Metals stay in the atmosphere majorly as aerosols and to a small extent as gases. Heavy metals emitted by combustion processes are highly soluble and reactive because there are of small sizes and this makes them easily soluble in rain especially at low pH. In forests, trace metals have been highly recognized as the major pollutants (Matschullat et al., 1995).

Rainwater can also be contaminated by Viruses, Bacteria and protozoa originating from faecal matter from birds, mammals and reptiles living in or with access to the catchment areas or the rain water storage facilities (Helmreich and Horn, 2008). Sazakli et al. analyzed three widely used bacterial indicators (Sazakli, *et al,* 2007). They found coliforms in 80.3% of rainwater samples, Escherichia coli and enterococci in 40.9% and 28.8%, respectively.

Mayo & Mashauri, 1991 also analyzed the physical, chemical and bacteriological quality of rainwater in cistern systems in the University of Dar es Salaam. Results showed that only 24% of the collected samples contained fecal coliforms, 45% of the samples tested positive for total coliforms and 54% tested positive for fecal streptococci.

A study carried out by Coombes et al., 2005 on the quality direct runoff from urban houses in Newcastle showed that the roof catchment impacts the chemical and the bacteriological quality of water stored in tanks via direct depositions of fecal waste from mammals and droppings from birds, decay of leaves and other organic debris, atmospheric decomposition of chemical pollutants and airborne micro- organisms.

The precipitation process scavages aerosols and trace gases from the atmosphere during. These trace gases and aerosol particles in the atmosphere play a major role in the rainwater chemistry by the in and out cloud rummaging processes. As a result, the following chemical species are typically found in rain water: ammonium, sodium, potassium, calcium, magnesium, hydrogen, sulphate, chloride, nitrate, carbonate and bicarbonate ions. Among these chemical species, hydrogen ion concentration (or pH) is very important for acid rain assessment.

Pure rain would have a neutral pH of 7. However pure rain is in equilibrium with the global atmospheric CO_2 thus this effect of CO_2 yields natural acidity and lowers the pH to 5.6. This pH value of 5.6 demarcates the line for acid rain. On the other hand,when the basic compounds (NH_3 and CaCO3) are not present. The pH value can be 5 as a result of the natural sulphur compounds. (Charlson and Rodhe, 1982).

Branco & Formosinho, 1982 measured daily the pH of Coinmbra, Portugal during between autumn 1978 to autumn 1980 and reported an average pH of 4.75. More than 30% of the samples had a pH less than 5 and generally the pH values had a large dispersion. He recorded a seasonal variation of 1.2 pH value between the highest average pH in autumn and the lowest in summer.

Khemani et al., 1985 reports that the alkaline property of soil dust has the ability to neutralize the acidic effects resulting from man-made gaseous pollutants. He reached this conclusion after the study he carried out on the pH of rain in Delhi between 1965 and 1966. In this study, he realized that rainwater remained alkaline even after 12 years of industrialization.

Rainwater can have alkaline values based on the fact cations neutralize the acidy of rainfall.

There is a possibility of rainwater still to be acidic even in pollutant free areas as a result of atmospheric carbon dioxide dissolving and attaining equilibrium with raindrops and form carbonic acid (Mukherjee, 1992).

Numerous studies that analyze the chemical parameters of stored rainwater have found that chemically rainwater meets the world Health organization guidelines of drinking water for a number of chemical parameters like, zinc, lead, iron, Copper among others, (Bidasha, 2015, Michaelides, 1986, 1989, Haebler & Waller 1987, Scott & Waller 1987).

Rainwater quality for domestic purposes is of great importance because some communities drink untreated rainwater.

The subject of rainwater quality is a complex one and even sometimes controversial. Numerous studies indicate that rainwater quality does not meet the WHO standards and some National studies mainly in terms of the bacteriological parameters (Mascaró, 2010, Bidisha, 2015). These findings don't imply that rainwater is of poor quality and unsafe to drink but they prompt further research about rainwater quality (Fujioka et al., 1991; Lye 1992).

Morgan, 1990 and Ockwell, 1986 proposed rainwater quality guidelines for rural areas, their sets of less strict guidelines allow the drinking of water with an average of 10Cfu/100ml. this far away from the WHO, 2017 guidelines that propose 0Cfu/ml.

2.6 Rainwater treatment

Water quality requirements and the potential uses are key aspects of any rainwater application. The quality standards vary depending on the potential uses of water. Therefore a specific water resource requires a specific level of treatment, depending on the potential use. This makes it important to investigate the initial water quality of each resource, in order to assess the potential uses, level of treatment, appropriate storage and distribution system.

The basic requirement for developing countries is a practicable treatment method which is inexpensive. A first improvement of rainwater quality can be achieved by cut off the first flush of a rain event, e.g. by first flush water diverters. They are easy to install, operate automatically and available in a number of different sizes to suit different requirements. In addition to the improvement of rainwater quality they reduce the tank maintenance.

• Disinfection — Disinfection improves microbiological quality of harvested rainwater. Chlorination is the commonest disinfection method used because; a) it accomplishes greater bacterial purification in minutes than storage achieves in an equal number of days. It thus avoids the construction of costly storage reservoirs. b) It is inexpensive and avoids, wholly or in part, the necessity for raw water storage. c) It provides extra security to the water against water-borne disease. d) It serves as a convenient accessory to the process of filtration.

Chlorination has to be applied after removal of the harvested rainwater from the storage tank, because chlorine may react with organic matter which settled to the bottom of the tanks and form undesired by-products. Chlorination should meet the amount of 0.4–0.5 mg/L free chlorine. Chlorination can be done by using chlorine gas, powder or tablets. Disinfection by chlorine has one limit, some parasites are resistant to low doses of chlorine. There is no doubt that the chlorination has proved to be one of the greatest advances in water purification and it has permitted the use of water supplies which otherwise would not have attained the required standard of purity. It should however be remembered that mere uncontrolled and haphazard addition of chlorine to water is not chlorination. On the contrary, such concept of chlorination leads to the failure of the process and invites complaints and criticisms. It is absolutely necessary for getting the desired results that the water to be treated should be properly applied in respect of method and dosage, that the contact time should be adequate and that the process should be well-controlled.

• Slow sand filtration — slow sand filtration is a cheap method to improve the bacteriological quality of harvested water. Slow sand filtration is a biological process, because it uses bacteria to treat the water. The bacteria establish a community on the top layer of sand and clean the water as it passes through, by digesting the contaminants in the water. The filters are carefully constructed using graded sand layers with the coarsest fraction on top and the finest at the base. Filtration efficiency depends on the development of a thin biological layer, i.e. a biofilm, on the filter surface. The biofilm layer requires cleaning every couple of months, when it gets too thick and the flow rate declines. The main limitation of slow sand filtration is that the micro-organisms can be only reduced rather than completely cleared in the treated rainwater.

• Pasteurization — pasteurization is achieved by combining ultraviolet radiation and the heat from solar energy. Since the sun is a free natural source of energy plentiful in most developing countries, this technique seems to be a reliable and effective low cost treatment method for harvested rainwater. The harvested water can be pasteurized by placing it in plastic bottles or bags or continuous flow (SODIS) reactors. The method works most effectively when water temperature reaches at least 50°C and the water is fully oxygenated. This treatment is very effective against E. coli and other pathogenic bacteria. The solar batch technology is sufficient for small households while the solar water disinfection respectively pasteurization as continuous flow system (SODIS reactor) can produce around 100 L of disinfected water per square meter of solar collector and day. However the technique is limited when the concentration of suspended solids is more than 10 mg/l.

Multiple water treatment methods may be necessary in some cases as one treatment method may be insufficient to improve the rainwater quality for a specific requirement, e.g. bathing. However, the simplest treatment method should be chosen if low-quality harvested water is adequate for applications such as toilet flushing or garden watering. The costs will not be justified if any complex treatment method is utilized. The harvested rainwater cannot be used for drinking after simple treatments. If the harvested water is subjected to the drinking water standard, some intensive treatments have to be taken. The coupling of a membrane filtration system and a disinfection system are commonly used for intensive treatment. If a judicious choice of the cut-off of the membranes is used, the obtained treated rainwater maybe drinkable as it contains very little viruses and bacteria.

However, boiling may be needed before drinking if the size of viruses or bacteria existed in the treated rainwater is large. The cost of this treatment is relatively high and filters may require a lot of maintenance.

Ultra-violet ray treatment:

It is found that the invisible light rays beyond the violet spectrum are very effective in killing all types of bacteria. For the purpose of generating these rays, mecury is enclosed in one or more quartz bulbs and electric current is then passed through it.

For effective disinfection, the water should be passed round the bulbs several times and depth of water over the bulbs should not exceed 10cm or so. The water should also be colourless and its turbidity should not be more than 15 p.p.m.

This treatment does not develop any taste or colour in the water because no chemicals are used in the process and there is no danger of overdose. But as the treatment is costly, it is unsuitable for large scale treatment plants. It can however be adopted for water installations of private institutions and especially at swimming pools where if chemicals are used as disinfectants there are chances of developing harmful effects to the skin of people taking bath.

UV disinfection systems are increasingly used in the pharmaceutical, food and beverage, chemical, drugs, diary and paint industry for processed water and wastewater. This method is proved to be safe, easy, convenient, reliable, dependent and cost effective with minimum maintenance requirements and no additional condition of any chemical. UV does not change the physical or chemical properties of water and can provide very high disinfection efficiency up to 99% or pyrogen free water. For microbial reduction, UV located downstream of the carbon filter is used in the tertiary treatment of wastewater.

CHAPTER THREE METHODOLOGY

3.1 Introduction

This chapter indicated how data for the study was collected, analyzed and interpreted in order to answer the research questions, thereby meeting the purpose of this study. This chapter therefore comprised of research design, study population, determination of sample size, sampling techniques, data collection methods, data collection instruments, quality control, data collection procedures, data analysis, measurement of variables, and ethical considerations.

3.2 Research Design

This study used the descriptive case study design. A case study is a strategy of inquiry in which the researcher explores in-depth a research problem, events, or more individuals (Creswell, 2009). Moreover, a case study is bounded by time and activity, and enables the researchers to gather detailed information using a variety of data collection procedures over a sustained period of time (Stake, 1995). Accordingly, this study used both quantitative and qualitative approaches to better understand the public perceptions and regulation of Rainwater quality, use and perceived risks of contaminants of rainwater and the rainwater quality at different stages of rainfall events. And also reviewed and proposed possible treatment methods and best practices that improve rainwater quality.

3.3 Study area

The study was conducted in sampled rural areas of Kiboga district. Kiboga is found in Central region of Uganda and lies on latitude 1^{o}00’ N and Longitude 31^{o}46’E and covers an estimated area of 1,586.9 km^2. It has an estimated population of 2012 people (Uganda Bureau of Statistics, 2014). This area falls in the Uganda’s dry lands commonly known as the cattle corridor. This area experiences a fairly bi-modal rainfall season like most parts of the country with the first season starting in March and end in early June and the second season beginning in the late August/September and ends in November/December. The people majorly practice livestock keeping, crop farming and mixed farming (Livestock and Crop).

3.4 Study population

In this study, the principal respondents were male and female who were practicing rainwater harvesting as evidenced by the presence of a rainwater harvesting system in their homes or were close to a communal rainwater harvesting system in Dwaniro and Kapeke sub counties. These categories of people were aged 18 years and above regardless of their religion, marital status, and education level.

3.5 Sampling strategies and Sample size

The study employed purposive sampling method for the selection of the study area, and principal respondents. The selection of the two sub counties in Kiboga: Kapeke and Dwaniro were informed earlier by (FAO, Uganda 2017), that 60% of the people in the cattle corridor don't have water for their animals, crop farming and domestic use. It was also earlier studied that people in the cattle corridor use Harvested rainfall mainly surface runoff as their main water source (Mugerwa *et al.*, 2014). This case study was also selected because it reflects full cycle rainwater harvesting (Roof runoff and surface runoff).

With respect to the sample size, data saturation (i.e. where no more new patterns or themes emerging) was achieved after a total of 40 (16 male and 24 female) respondents had been interviewed and a total of two (2) focus group discussions had been held.

3.5.1 Collection of Rainwater Sampling

Rainwater samples were collected in two different locations which include; Kapeke and Dwaniro sub counties in Kiboga district. These locations are rural farm areas and there is no industrialization and urbanization in these areas. These two locations were selected because people here practice both surface and roof runoff making it possible to represent a full rainwater harvesting cycle (direct rain, roof runoff and surface runoff)

3.5.1.1 Direct rain Collection

A total 3 samples was collected from one location.

Large plastic Basins were used to collect rain water sample. The basins were placed on a raised platform 1.5m above the ground in an open environment in order to ensure that rainwater has not contact with any object before getting to container. Mounting the samplers also helped in avoiding the rain splashing soil, this is in line with the recommended standard literature (bidisha, 2015, Singh et al., 2007 and Lara et al). The collected pure rain sample was transferred from the basins to the 1 litre plastic bottles with the aid of a funnel. The sample was then put in the cool box ready and transported to the laboratory for quality analysis.

A total 3 samples was collected from one location.

3.5.1.2 Roof runoff collection.

A total of 8 samples (4 samples per Roof top) were collected from two different roofs. Sampling was done once after every two weeks during the wet month of May and June

Gutters made of plastic pipes were used to convey water from corrugated Iron sheets to 100L plastic tanks fitted with a tap at the bottom. The collected sample was transferred to the 1L plastic bottles with the aid of the tap. The sample was then put in the cool box and transported to laboratory for quality analysis.

3.5.1.3 Surface Runoff Collection

A total of 8 samples (4 samples per Valley tank) were collected from two valley tanks. Sampling was done once after every two weeks.Surface runoff samples were collected from two different Valley tanks in Kiboga District. The valley tanks have a trapezoidal shape and there are mere excavations with a capacity of 10,000 cubic meters. They collect runoff during wet seasons and the water was meant for livestock watering in dry spells but due to water scarcity in these areas, some People use this water for domestic purposes. Samples with sterilized scoop fitted with a handle and transferred to the 1Lplastic bottles and, stored in a cool box and transported to the laboratory for physical, chemical and microbiological analysis.

All results of analysis were compared with recommended drinking water guidelines by the Ugandan national standards and the World Health Organization (WHO).

3.5.2 Rainwater Quality Analysis

3.5.2.1 Determination of Turbidity

Turbidity was measured using a DR/890 Colorimeter. Rainwater samples were put in a 50ml sample cell and placed in a DR/Colorimeter; the program number 5 for Turbidity was pressed. The read button was pressed on the DR/Colorimeter. The displayed value on the DR/colorimeter was recorded as the turbidity

3.5.2.2 Determination of Color

Color was measured using a DR/890 Colorimeter. Rainwater samples were put in a 50ml sample cell and placed in a DR/Colorimeter; the program number 17 for color was pressed. The read button was pressed on the DR/Colorimeter. The displayed value on the DR/colorimeter was recorded as the color.

3.5.2.3 Determination of pH

pH was measured using a digital pH meter. The pH meter was switched on and allowed to warm for some time.The water sample was put in a beaker, followed by resining the sensor of the pH meter using distilled water. The sensor was then dipped in the water sample in the beaker and left there until a stable reading was displayed on the pH meter screen. The stable reading was recorded at the pH.

3.5.2.4 Determination of Iron Total

Iron total was analyzed using Ferro Ver Method (using powder pillows)

The program number of 33 for iron was pressed on the DR/890Colorimeter followed by pressing enter button; mg/l, Fe and a zero mark were displayed.

A clean sample cell was filled with 10ml of the sample (blank), the blank was placed in the DR/Colorimeter cell holder, tightly covered with instrument cap. The zero button was pressed and 0.00mg/l was displayed.

Another sample cell was filled with 10ml of the sample and contents of ferro Ver Iron Reagent Powder Pillow. The sample cell containing the reagent was shaken for one minute and left to settle for two minutes. The sample was placed in DR/890Colorimeter cell holder, tightly covered with instrument cap. Read button was pressed and reading was displayed.

3.5.2.5 Determination of E.Coli

E. coli was analyzed using the Chromo cult Augur method.

The plates were autoclaved at 120^oC.

0.1ml of the sample was diluted in 100ml of distilled water

0.1ml of the diluted sample was poured on the plates using the petite tube and spread using a spreader which was previously sterilized using ethanol and then put on a flame. The sample was spread carefully but staying a half a centimeter away from the sides of the plate.

The samples were there after incubated at 37^oC for one day.

After the one day incubation, the developed colonies of E.coli which are bluish to purple in color were counted.

3.5.2.6 Determination of Nitrate

Nitrate was analyzed using the Cadmium Reduction method (using powder pillows) with the aid of a DR/890 Colorimeter.

The sample was prepared by filling a sample cell with 10ml with the rainwater quality sample. Contents of Nitra Ver 5 Nitrate powder pillow was added in the sample cell. The sample cell was shaken for one minute and left to settle for 2 minutes.

The DR/colorimeter program number 51 was pressed then followed by pressing enter. The zero mark was displaced.

The sample cell containing Nitra Ver 5 Nitrate powder pillow was capped and followed by pressing the read button. The displayed value on the DR/Colorimeter was recorded as the nitrate value.

3.5.2.7 Determination of Total Phosphorus

Total Phosphorus was analyzed using Persulphate Digestion method.

50ml of the sample were taken using an acid rinsed 50ml volumetric flask and transferred to total Phosphorus bottles.

One drop (0.05ml) of phenolphthalein indicator was added in the sample, this was followed by adding 0.5g of potassium persulphate.

The prepared sample was autoclaved for 30 minutes at 121^{o}C, after digestion, the sample was left to cool in the autoclave for at least 10 to 20 minutes. The sample was then removed from the autoclave and left to cool further.

On cooling one drop of phenolphthalein indicator solution was added.

The sample was neutralized to a faint pink color by the use of 1N or 5N sodium hydroxide, using a pipette.

The contents of the bottle were transferred to a 100ml volumetric flask. The bottle was rinsed twice with distilled water and transferred the washings to a volumetric flask to make up a volume of 100ml.

50ml was taken from the diluted sample and added 8ml of combined reagent (50ml of 5NH_2SO_4 , 5ml of Potassuim antimonyl tartrate, 15ml of mmonuim Molybdate, and 30ml of Ascorbic Acid)

The sample was mixed well for 10 to 20 minutes for maximum color development.

Then finally the sample was then put in the spectrophotometer and read 880nm within 30 minutes.

3.5.2.8 Determination of Lead and Zinc

200 ml of the rainwater samples were subjected to slow evaporation at 70°c- 80°c to bring down the volume of water samples from 200 ml to 20 ml. The determination of lead and Zinc was done using an Atomic Absorption Spectrometer (Perkin Elmer PE 3110) by Flame method.

3.6 Data Analysis

All responses from the questionnaire were numerically coded during data collection. The collected data was entered into a computer data base using IBM SPSS 25. The response types included; Rankings, Bivariate (Yes/No), and numerical scale items for example Likert scale (a 7 point scale where 1= strongly disagree and 7= strongly agree). Analysis was done using descriptive statistics with the aid of IBM SPSS 25 software.

CHAPTER FOUR RESULTS AND DISCUSIONS

4.0 Introduction

This chapter presents the main findings for the objectives of the study.

50 respondents were selected to participate in the exercise but only 40 respondents were interviewed. The reminder chose not to participate. The study employed purposive sampling method for the selection of the study area. Respondents selected for the study were those practicing rainwater harvesting as evidenced by the presence of a rainwater harvesting system or were close to a communal rainwater harvesting system.

4.1 Public perceptions about rainwater quality, use, practice, regulation and perceived risks of contamination.

4.1.1 Demographic characteristics of respondents

This section presents the demographic characteristics of the participants of the study. The study involved a total of 40 respondents consisting predominantly of women (60%) and men (40%). 70% of the respondents were married men and women, 5% percent had been never married/singles and the remaining were either divorced or widowed or even single parents. 85 % of the participants had attained some level of education; however, the majority (62%) only stopped at primary level education, with 8% reported having attained tertiary, and 12% secondary education. Also, 89% of the participants were engaged in livestock and crop farming as their main source of livelihood.

Table 1: Demographic features of the respondents

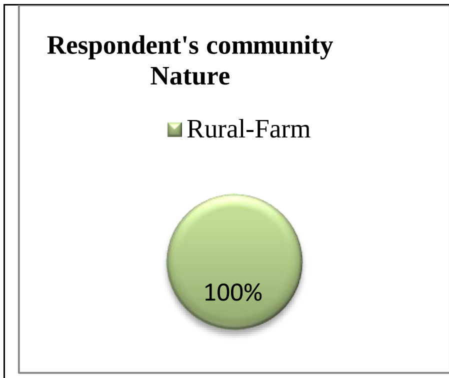

Figure 1: Nature of the community

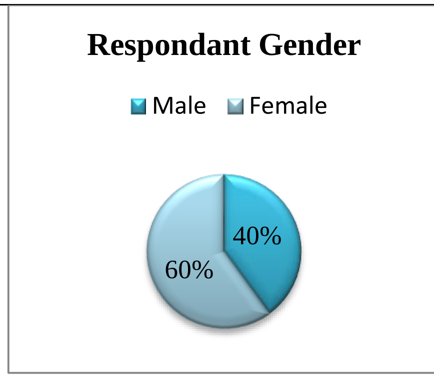

Figure 2: Respondent's Gender

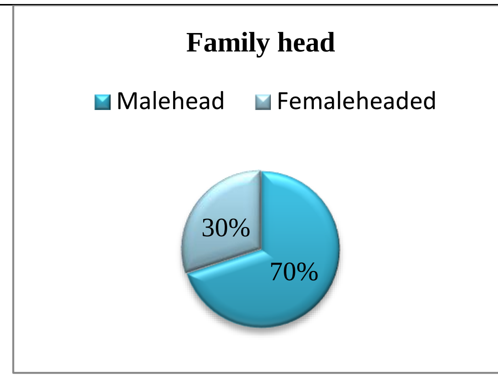

Figure 3: Type of family Head

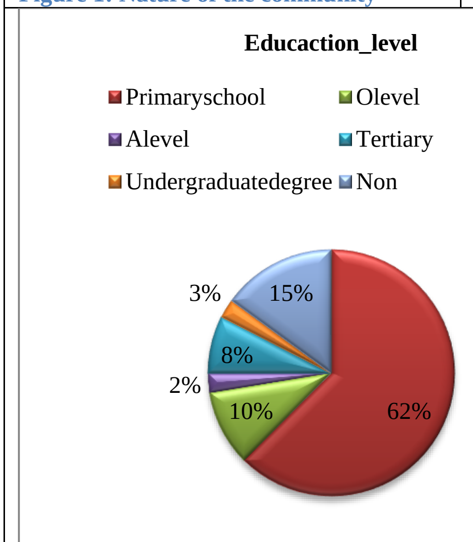

Figure 4: Educational level

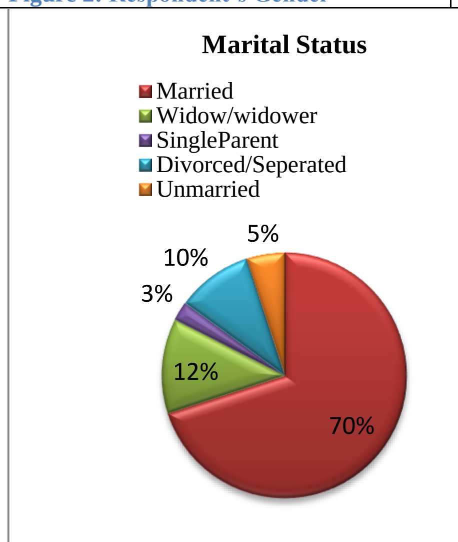

Figure 5: Marital status

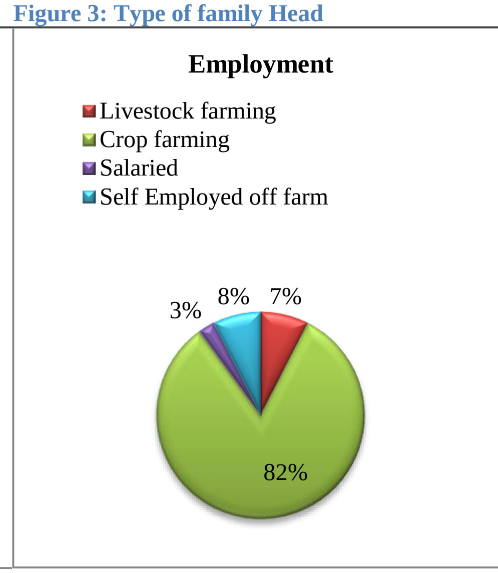

Figure 6: Employment

4.1.2 Water sources, usage, testing and treatment

85 percent of the respondents use rainwater as their main water source and the remaining 15% use borehole water as their main water source. From the study, 70% of the respondents use surface runoff collected and stored in communal valley tanks, the remaining collect their rainwater from roofs and store their water in mainly plastic tanks. The harvested rainwater is used for different purposes, 97.5% of the respondents drink rainwater, 100% of the respondents used it for other domestic uses, 25% of the Respondents use it for Irrigation and 52.5% of the respondents use it for livestock watering. All the respondents have never carried out a water quality test of their rainwater. 87.5 of the population boil their rainwater for only drinking

purposes. 75% of the respondents use rainwater throughout the year and the remaining 25% use rainwater only during the rainy season.

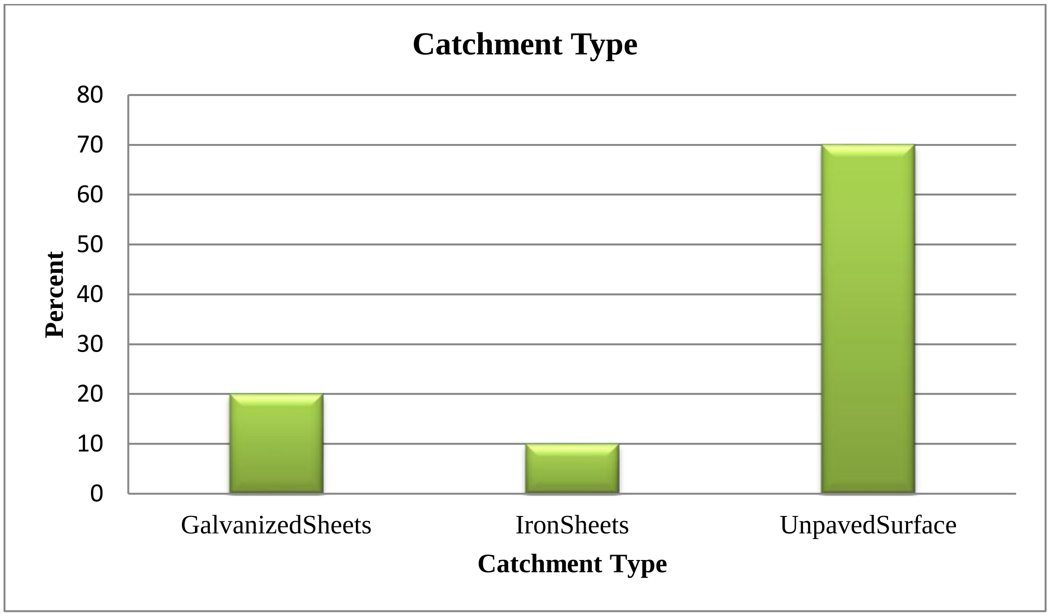

Figure 7: The catchment type

70% of the respondent use surface runoff collected in the communal valley tanks, and the remaining 30% use roof runoff stored in plastic, concrete and metallic tanks.

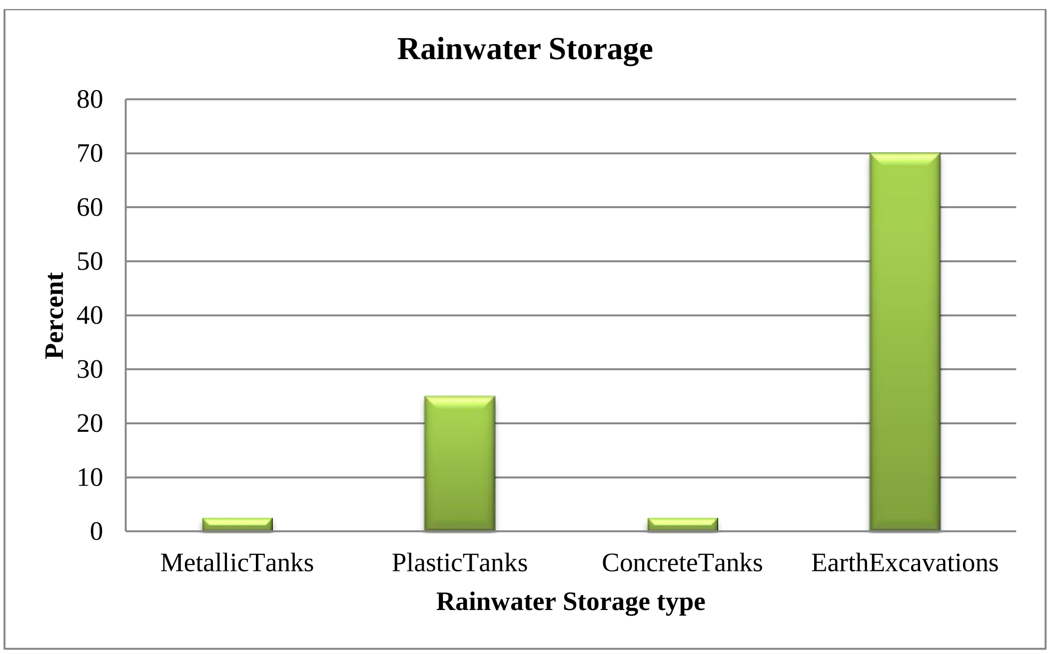

Figure 8: Type of Rainwater storage

70% of the rainwater is stored in the communal valley tanks (earth excavations), 10% store their water in plastic tanks and the remaining store their water in concrete and metallic tanks.

4.1.3 Perceived Rainwater quality, safety and threats

Majority of the respondents (62.5%) ranked their rainwater quality as good to excellent. When asked about safety of their rainwater, 47.5% feel their rainwater is safe or very safe from contamination.

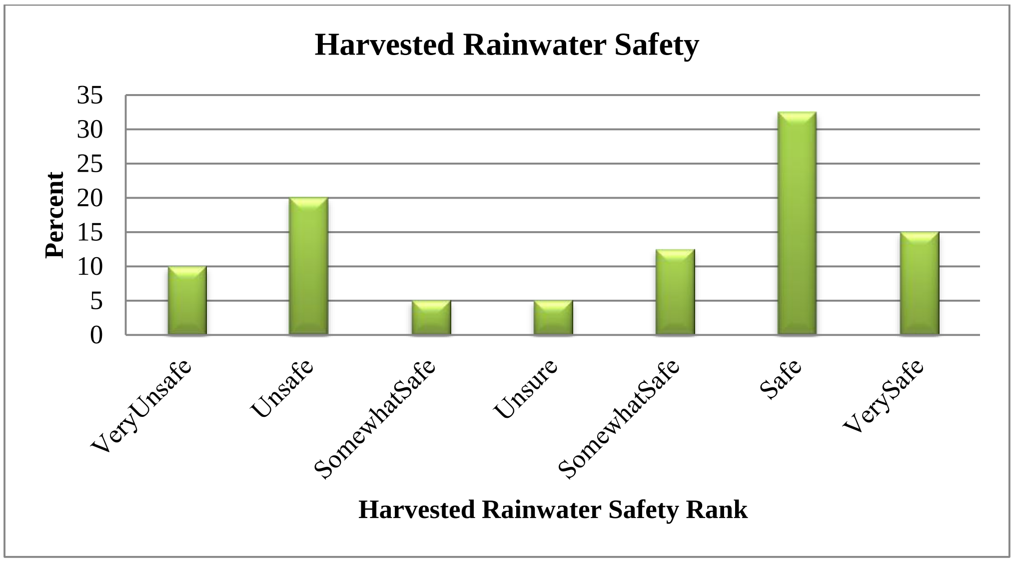

Figure 9: Harvested Rainwater Safety as Ranked by the Respondent

Challenges with Harvested rainwater cited most frequently included, change in color after rainfall events for surface runoff and growth of organisms in water for both surface and roof runoff.

4.1.4 Threats to Rainwater Quality

In order to identify the threats to surface runoff water quality, participants were provided with a list of nine likely sources of contamination. Silt from erosion was ranked as the greatest (70%) threat to surface runoff quality, followed by Bacteria from livestock waste at 55% ranking, Faecal contamination ranked at 50% and contamination from chemical residues from pesticides was 42.5% ranking . 72.5 of the respondents were not sure whether there was a contamination threat from heavy Metals.

Table 2: Threats to Rainwater Quality

Threat	Agree (%)	Unsure (%)	Disagree (%)
Heavy metals (Iron, zinc, lead.)	7.5	72.5	20
Industrial pollution	2.5	0	97.5
Traffic pollution	17.5	15	67.5
Bacteria from livestock waste	55	5	40
Chemical residue From pesticides	42.5	7.5	50
Fertilizers from Agricultural operation	30	17.5	52.5
Chemical residue From herbicides	37.5	15	47.5
Bacteria from faecal matter	50	2.5	47.5
Silt from erosion	70	0	30

4.1.5 Regulations on Rainwater quality and use

Five statements in regard to regulation were presented in the questionnaire and the respondents ranked them as tabled below. 67.5% of the respondents feel there is need to formulate Rainwater use act/policy, 92.5% of the respondents feel Rainwater treatment before use should be mandatory. 75% of the respondents feel they do enough in their capacity to protect Rainwater quality and 47.5% of the respondents feel there is no enough awareness about rainwater quality among the users.

Table 3: Attitudes towards Rainwater quality Regulations

	Agree (%)	Unsure (%)	Disagree (%)
There is enough awareness about rainwater quality	45	7.5	47.5
There exist strict Air pollution laws in my area.	10	7.5	82.5
It is mandatory to have a water treatment system for rainwater.	92.5	0	7.5
Enough attention is given to protect Rainwater quality	75	0	25
I feel there is need to formulate the rainwater use act/policy	67.5	5	27.5

4.1.6 People's attitudes towards important issues that affect Rainwater Quality

7 items were put on a likert scale to measure people's attitudes towards important issues that affect Rainwater quality as in the table below. 97.5% of the respondents agreed that ensuring

water safety through an appropriate and clean catchment, proper conveyance systems, proper storage and delivery has a positive impact on rainwater quality. 97.5% of the respondents agreed that rainwater treatment before use is one of the important factors to ensure a good rainwater quality. Also 92.5% of the respondents agree that managing faecal contamination from humans, animals and birds can ensure good rainwater quality.

Table 4: Attitudes towards factors affecting Rainwater quality

Aspect	Agree (%)	Unsure (%)	Disagree (%)
Ensuring water safety	97.5	0	2.5
Water treatment before use	97.5	0	2.5
Protecting air quality	30.0	62.5	7.5
Protecting forests	65.0	17.5	17.5
Managing domestic waste	77.5	15.0	7.5
Managing faecal Contamination	92.5	2.5	5.0
Protecting wetlands	75.0	12.5	12.5

4.2 Rainwater quality results (pure rain, roof runoff and surface runoff)

4.2.1 Pure rainwater quality results

Pure rainwater quality results

Parameters	Dates		
	28/05/2018	11/6/2018	26/06/2018
E.Coli (Cfu/100ml)	0	0	0
Turbidity (FAU)	6	10	14
pH (upH)	6.31	5.84	5.95
Color (PtCo)		188	145
Iron (Fe^{2+}) (mg/l)	0.05	0.04	0.09
Zinc (mg/l)	0.0157	0	0
Lead (mg/l)	0.14	0.1	0.12

Table 5: Summarized Pure Rainwater Quality Results

Parameter	Pure Rainwater Range			WHO (2017) Recommendation	Uganda National Standards
	Max	Min	Mean		
E.Coli (Cfu/100ml)	0	0	0	0	0
Turbidity (FAU)	14	6	10	<5	<5
pH (upH)	6.31	5.84	6.03	6.5-8.5	6.5-8.5
Color (PtCo)	188	145	166.5	<15	<15
Total Organic Carbon (mg/l)	ND	-	-		
Iron (Fe2+) (mg/l)	0.09	0.04	0.06	<0.3	<0.3
Zinc (mg/l)	0.0157	ND	0.0157		
Lead (mg/l)	0.14	ND	0.14	0.01	0.01

Generally most of the parameters analyzed met the WHO Drinking water guidelines and the Ugandan standards for portable water.

Pure rainwater samples were collected in three different locations, the laboratory results from the direct sampling from all the three sites showed that the pH values ranged between 5.84 to 6.31indicating slightly acidic nature of rain water. These values are in line with findings of Bidisha, 2015 who found out a mean range of 5.35 to 6.64 at different sites in India. However the obtained range also does not divert so much from the reference pH level of 5.6 according to a study by Charlson and Rodhe, 1982. The pH of pure rainfall (Natural precipitation) is controlled by the dissolved Carbon dioxide in the atmosphere. The pH is also significantly influenced by the introduction of acidic components in the atmosphere, generated from civil and Industrial activities (Primerano *et al.*, 1998). In areas without pollution, the pH value for natural precipitation is approximately 5.6 as result of carbonic acid produced from CO_2 equilibrium. Rainwater with pH values ranging from 5 to 5.6 is considered to be with enough buffering capacity, which literally implies that the site is not impacted; on the other hand pH values less 5 are evidence of anthropogenic sources contributing to the acidity of rain (Jaeschke, 1986). The mean pH of 6.03 was observed indicating a slightly acidic situation.

Furthermore according to (Charlson and Rodhe, 1982; Gulsoy et al.,1999; Okay et al., 2002), in the absence of basic compounds such as $CaCO_3$ and NH_3, pH values may be expected to range from 4.5 to 5.6 as a result of natural sulfur alone.

There are occurrences of alkaline rainwater according to reports of Lara *et al.,* 2010 in Mexico and Zhang *et al.,* 2003 in Tibet. However, for this particular study, Pure Rainwater samples generally showed low pH values, this could be due to the reason that samples were collected in the rainy season and in rainy periods, when precipitation was greater and when there were consecutive days of rainfall, which rain could have led to a considerable decrease in the concentration of solids in the collected rainwater.

Zinc

Overall analysis showed low concentrations of zinc in the pure rain/direct rainwater samples and the sample fulfilled the standards. High lead concentrations come from coal burning, smelting of non-ferrous metals and fossil fuels, (Payus & Meng, 2015). Since none of those activities exist in the study area, lower zinc concentrations were recorded.

Lead

Lead samples were within the standards. According to a study by (Payus & Meng, 2015), lead is a non-crust dominated trace metal, the concentration of lead can vary from one rainfall event to another. This explains the detection of lead in the rainwater from the study area. Motor vehicle emissions and industrial activities also emit lead substances in the atmosphere (Payus & Meng, 2015). There are no industries in Kiboga and there exist low traffic in the area. This can be reason for the very low lead values recorded.

4.2.2 Roof runoff quality results

Roof runoff quality results

	Dates							
	18/05/2018		28/05/2018		11/6/2018		26/06/2018	
Parameters	PT1	PT2	PT1	PT2	PT1	PT2	PT1	PT2
E.Coli (Cfu/100ml)	36	56	11	95	15	0	55	6
Turbidity (FAU)	4	0	1	1	5	1	0	2
pH (upH)	5.61	5.47	5.3	5.87	4.99	4.69	5.48	6.26
Color (PtCo)	99	30	46	51	102	31	25	97
Iron (Fe2+) (mg/l)	0.11	0.12	0.1	0.06	0.13	0.25	0	0.09

PT1- Site one
PT2 –Site two

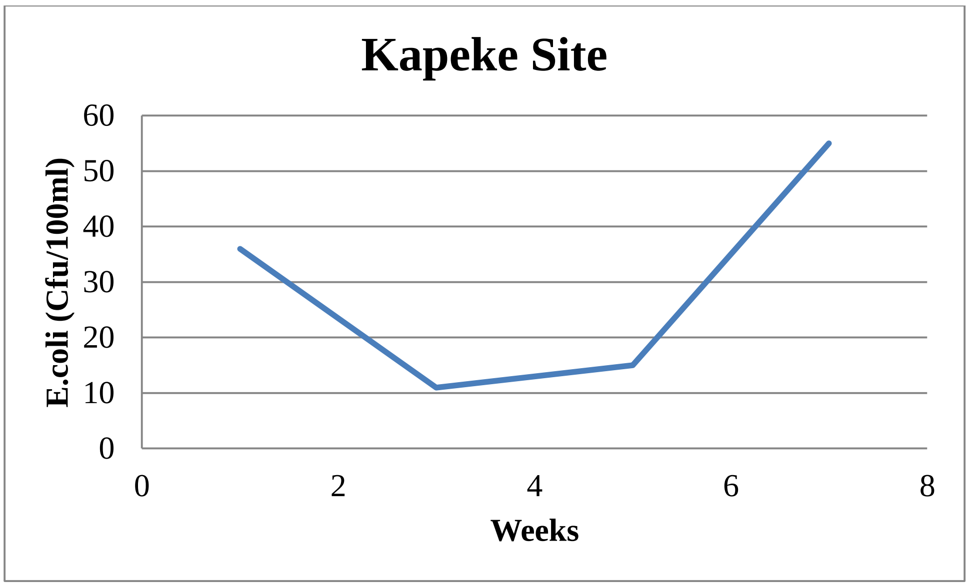

Figure 10: E.coli results in Rainwater from Kapeke site, for May and June, 2018

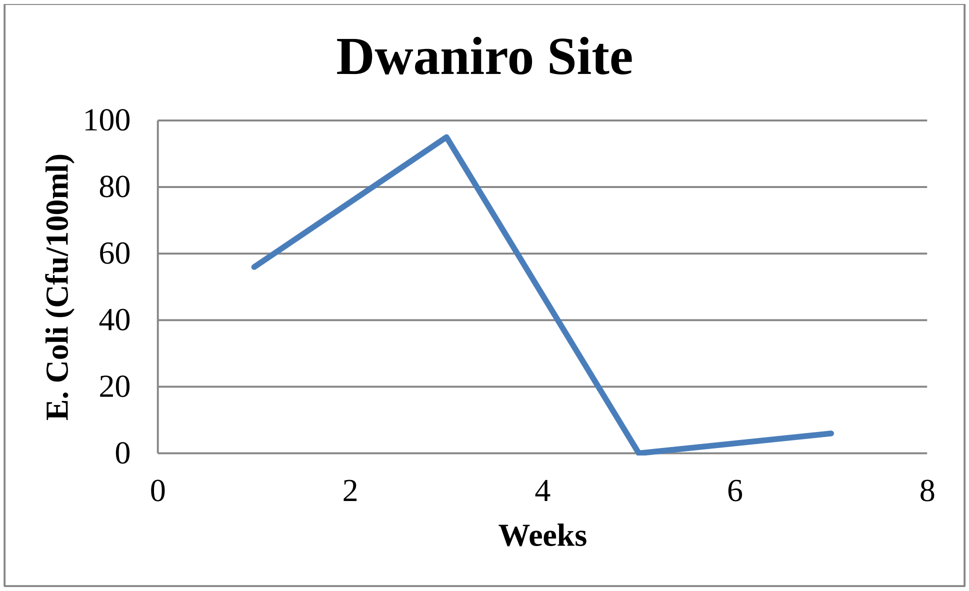

Figure 11: E.coli results in Rainwater from Dwaniro site, for May and June, 2018

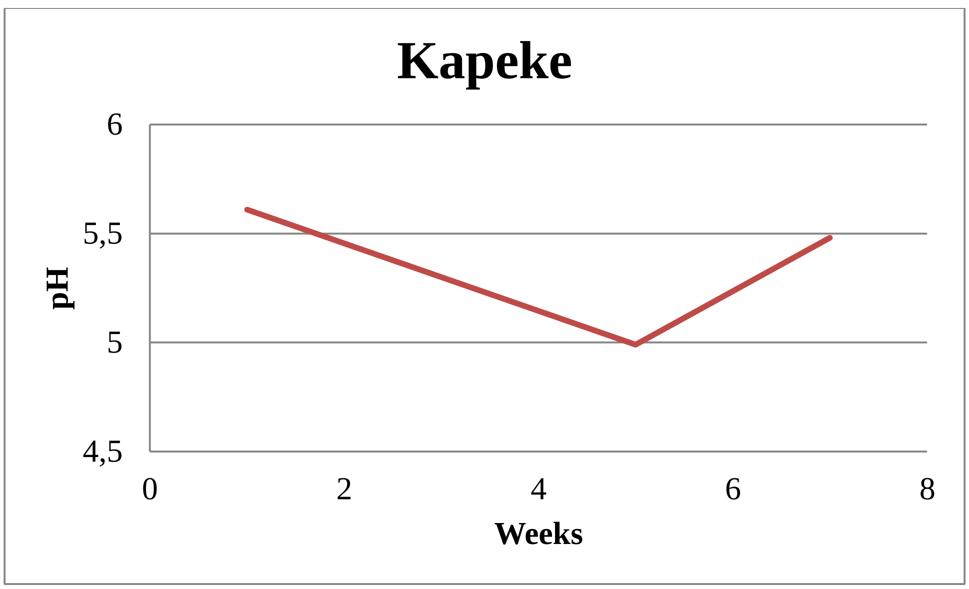

Figure 12: pH results in Rainwater from Kapeke site, for May and June, 2018

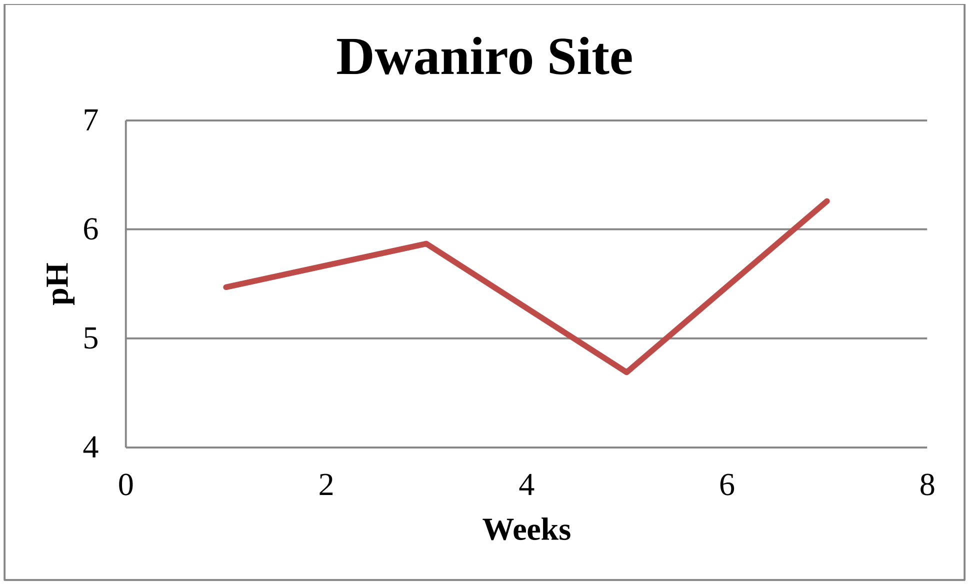

Figure 13: pH results in Rainwater from Dwaniro site, for May and June, 2018

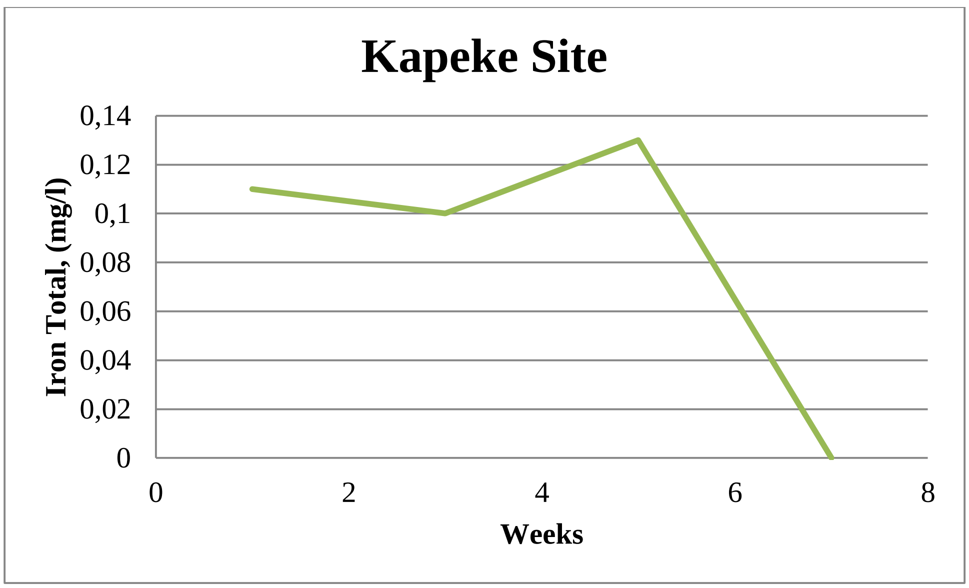

Figure 14: Iron Total results in Rainwater from Kapeke site, for May and June, 2018

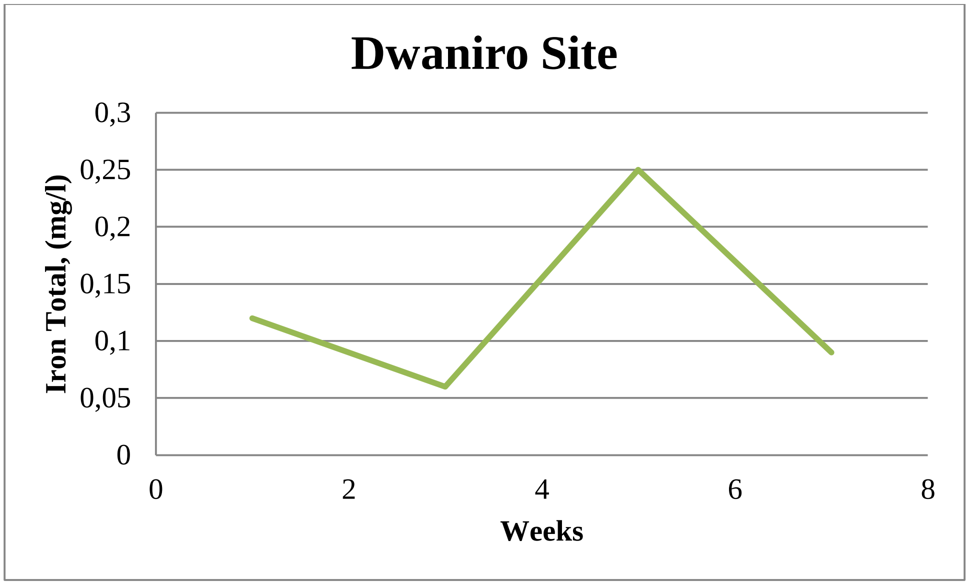

Figure 15: Iron Total results in Rainwater from Dwaniro site, for May and June, 2018

Table 6: Summarized Roof Runoff quality Results

Parameter	Roof Runoff collected			**WHO (2017) Recommendation**	**Uganda National Standards**
	Range				
	Max	**Min**	**Mean**		
E.Coli (Cfu/100ml)	95	0	34.2	0	0
Turbidity (FAU)	5	0	1.8	<5	<5
pH (upH)	6.26	4.69	5.46	6.5 – 8.5	6.5 – 8.5
Color (PtCo)	102	25	61.2	<15	<15
Iron (Fe2+) (mg/l)	0.25	0	0.11	<0.3	<0.3

ND - Not Detected

The pH values of the three sites ranged from 4.69 to 6.26, but in general there were low pH values from all the roof runoff samples. According to Foster, 1996, there are a number of factors that influence the quality of roof runoff, these factors are not limited to but include; the roof material itself, meteorological factors, the rainfall event, the location of the roof and the chemical properties in the atmosphere. It has been observed in this study that roofs tend to enrich rainwater as it falls on the roof catchment as compared to free fall rainwater. This finding is in agreement with the earlier studies by Bidisha, 2015, Olabanji & Adeniyi, 2005.

Rainwater collected from roof catchment are mainly polluted by atmospheric deposition. Low pH values at some sampling sites can also be attributed to the effect of decomposing leaves which lead to rainwater acidification and acid production. This happened in roof locations with trees.

Usually pH has no direct effect on human healthy (WHO, 2017). However, low pH values of harvested rainwater can corrode metallic rainwater tanks or pipes, which in the end my affect the test and odor of the rainwater. There was 100% detection of Escherichia coli (E.Coli) in the roof runoff; E. coli is an important water quality parameter since it is considered to be the most suitable indicator of fecal contamination. Coliforms live in the intestines of animals and are found in their feces.

Microbial contamination in RWHs is majorly as a result of pollutants from decomposing leaves, animal's fecal matter and bird droppings. During the dry season, micro-organisms from accumulated dust, leaves, animal and bird droppings is washed away during heavy pours and ends up in the storage systems. Not all coliform bacteria cause diseases; some studies concluded that there are very low risks of contracting illness from consuming microbial contaminated rain water (Heyworth, 2001 and the Australian Government Department of Health, 2011). However detection of E. coli indicates possible presence of pathogens. Therefore presences of E. coli suggest that caution should be taken to remove microbial contamination.

According to a study carried out by Kim and Han in 2014, Growth of biofilms at the bottom or along the walls of rainwater tanks can absorb contaminants from rainwater thus controlling the microbial quality of Rainwater. The study emphasizes that Tanks designed with increased surface to volume ratio maximize the performance of Biofilms.

4.2.3 Surface runoff

Surface Runoff Results

Parameters	**Dates**							
	18/05/2018		**28/05/2018**		**11/6/2018**		**26/06/2018**	
	VT1	VT2	VT1	VT2	VT1	VT2	VT1	VT2
E.Coli (Cfu/100ml)	135	70	175	105	40	120	235	90
Turbidity (FAU)	40	985	28	1020	25	1024	30	998
pH (upH)	6.8	6.97	6.6	7.1	6.1	7.19	6.99	7.14
Color (PtCo)	280	9342	305	10240	293	9080	291	10500
TOC (mg/l)	0.08	0.021	-	-	-	-	-	-
Iron (Fe2+) (mg/l)	0.78	2.7	0.71	2.65	0.8	2.72	0.63	2.68
COD	32	41	35	38	49	29	28	40

TDS (mg/l)	163	2730	156	2598	124	2272	130	2393
N total (NO3-N) (mg/l)	-	-	-	-	0.4	9.3	0.6	5.55
P total (mg\l)	0.16	4.472	0.2	4.793	0.22	5.452	0.218	5.21

VT1- Site one (Kapeke)

VT2- Site two (Dwaniro)

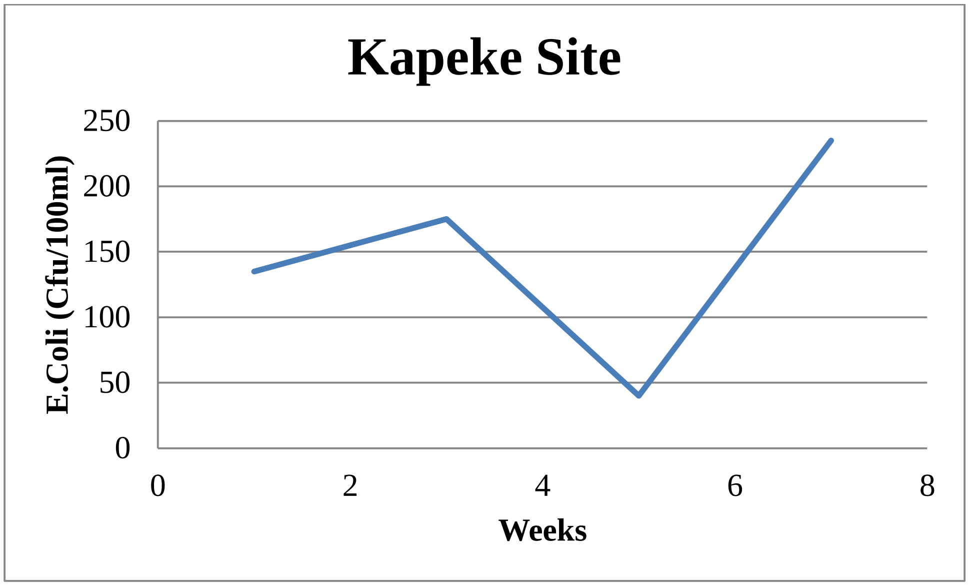

Figure 16: E.coli results in surface water from Kapeke site, for May and June, 2018

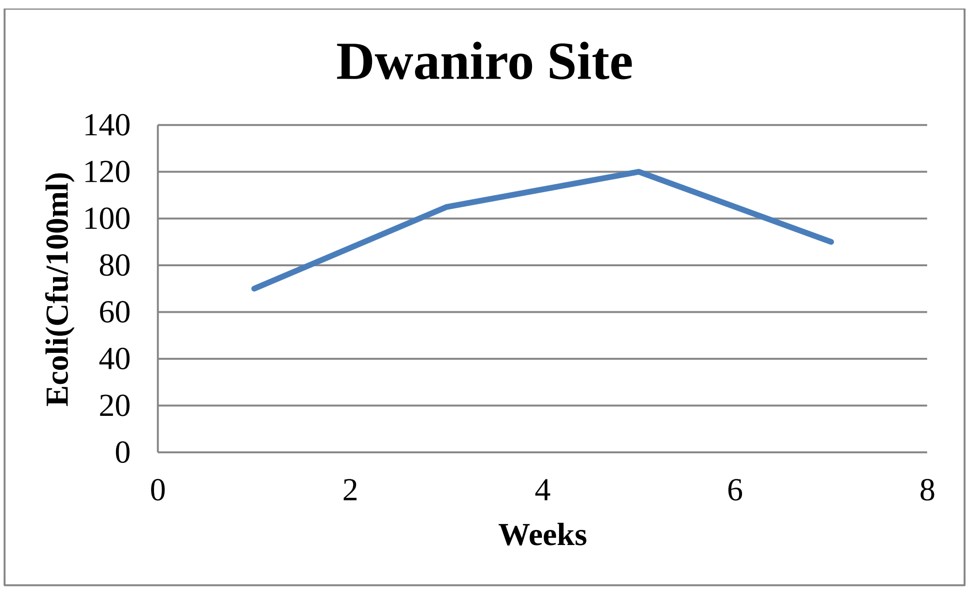

Figure 17: E.coli results in surface water from Dwaniro site, for May and June, 2018

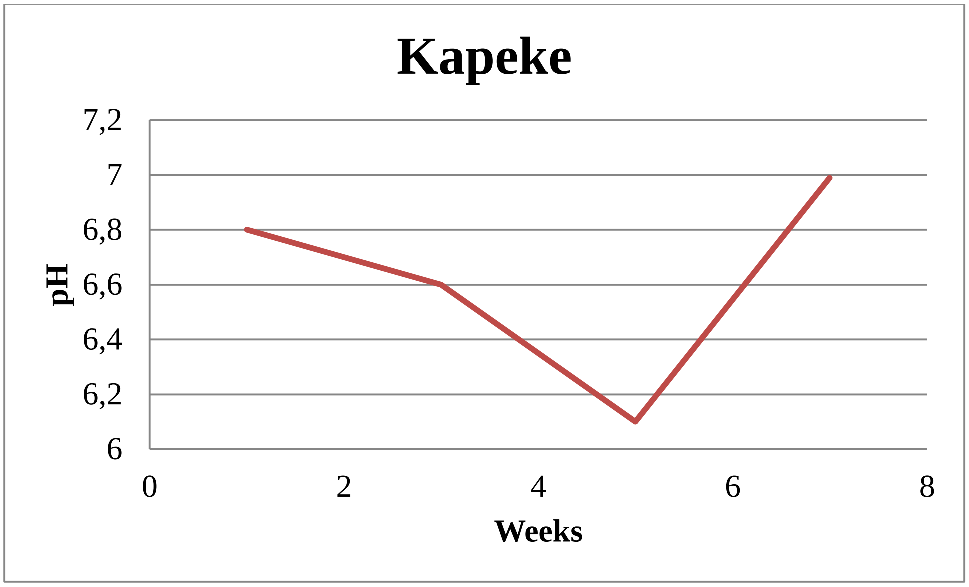

Figure 18: pH results in surface water from Kapeke site, for May and June, 2018

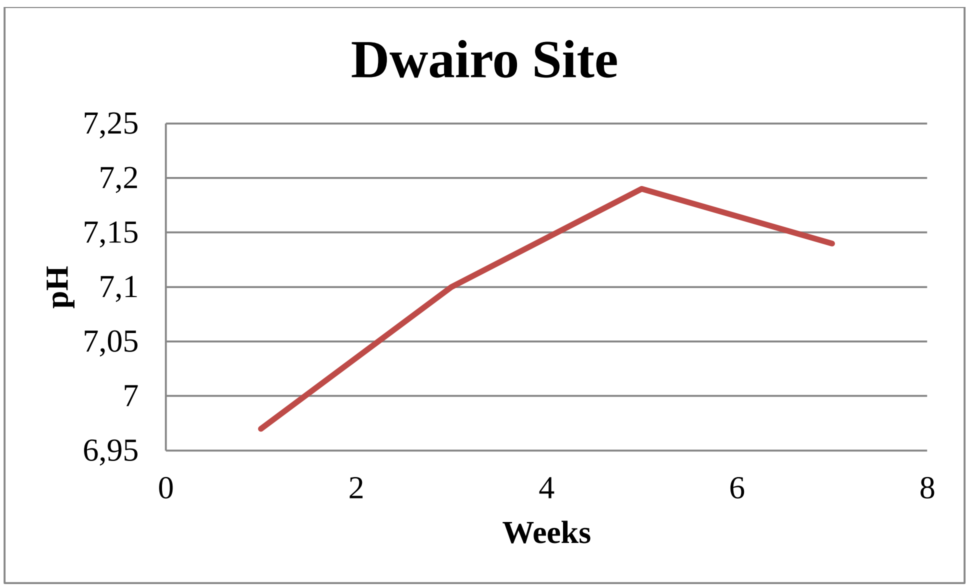

Figure 19: pH results in surface water from Dwaniro site, for May and June, 2018

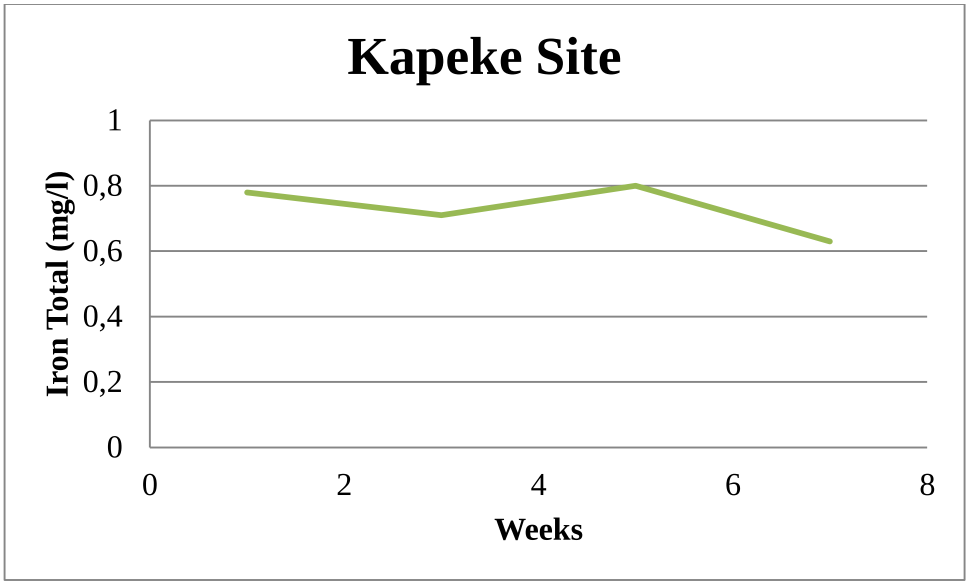

Figure 20: Iron total results in surface water from Kapeke site, for May and June, 2018

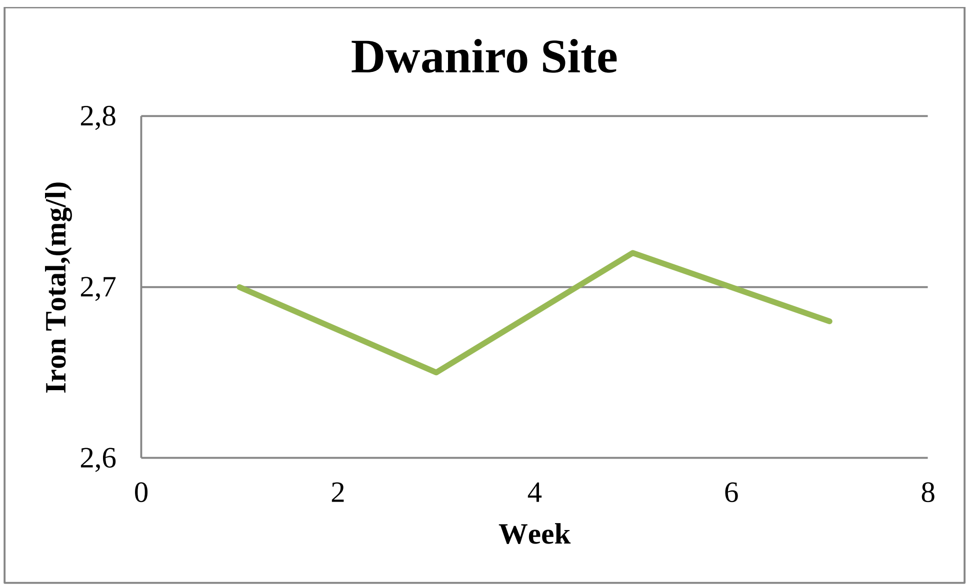

Figure 21: Iron results in surface water from Dwaniro site, for May and June, 2018

Table 7: Summarized Surface Runoff quality Results

Parameter	Surface Runoff Collected in Valley taks				
	Range			WHO (2017) Recommendation	Uganda National Standards
	Max	Min	Mean		
E.Coli (Cfu/100ml)	235	40	121	0	0
Turbidity (FAU)	1024	25	519	<5	<5
pH (upH)	7.19	6.10	6.86	6.5 – 8.5	6.5 – 8.5
Color (PtCo)	10500	291	5041	<15	<15
COD	49	28	36.5		100
TDS (mg/l)	2730	124	1321	<600	<1500
Total Organic Carbon (mg/l)	0.08	0.021	0.051		
Iron (Fe2+) (mg/l)	2.72	0.63	1.71	<0.3	<0.3
N total (NO3-N) (mg/l)	9.2	0.4	3.96		30
P total (mg\l)	5.452	0.218	2.591		

E.Coli

As few as 100 organisms can cause infection (WHO, 2017), the presence of high volumes of E.Coli in the valley tanks can be attributed to livestock excreta since this is one of the major income generating activity in these areas and also human excreta since during the questionnaire interview it was revealed that some cattle keepers practice open defecation. In the O'Connor DR (2002) Report of the Walkerton Inquiry, it is reported that a water supply system was contaminated by cattle waste which led to 7 deaths and more than 2300 illnesses. Therefore the presence of an average of 121cfu/100ml as per the study findings put the community at a high risk of infection.

Turbidity

The surface runoff collected exhibited a high value of turbidity. This can be attributed to the land use practices in this area; it was observed that there are crop farms up stream of the valley tanks. These recorded high levels of turbidity can lead to staining of materials, fittings and clothes exposed during washing. It also interferes with the effectiveness of treatment and it is recommended that before disinfection of water, the turbidity should be as low as 5NTU. This visible turbidity also affects people's acceptability of their water.

Total dissolved solids

This parameter has no health effects in drinking water. But the high values of TDS more than 600mg/l recorded in the valley tank waters indicates that the water is unpalatable and objectionable to the consumers owing to excessive scaling of the household appliances.

Nitrate NO_{-3}

Nitrate naturally occurs in the environment and is an important nutrient for plants, it is present in all plants at varying concentrations and it forms part of the nitrogen cycle.

The presence of Nitrate in the surface runoff is as consequence of agricultural activity in this area which includes the usage of inorganic nitrogenous fertilizers and also from oxidation of nitrogenous waste products in animal excreta since there was evidence of livestock farming.

4.2.4 Quality Comparisons for common parameters of Pure Rainwater, Roof runoff collected in tanks and surface Runoff collected in Valley tanks

Table 8: Comparisons of common parameters of direct rain, Roof runoff and surface runoff

Parameter	Pure Rainwater			Roof Runoff in Tanks			Surface Runoff in Valley Tanks		
	Range		Mean	Range		Mean	Range		Mean
	Max	Min		Max	Min		Max	Min	
E.Coli (Cfu/100ml)	0	0	0	95	0	34.2	235	40	121
Turbidity (FAU)	14	6	10	5	0	1.8	1024	25	519
pH (upH)	6.31	5.84	6.03	6.26	4.69	5.46	7.19	6.10	6.86
Color (PtCo)	188	145	166.5	102	25	61.2	10500	291	5041
Total Organic Carbon (mg/l)	ND	ND		ND	ND		0.081	0.021	0.051
Iron (Fe2+) (mg/l)	0.09	0.04	0.06	0.25	0	0.11	2.72	0.63	1.71

It can be observed that the quality of rainwater kept on depreciating from direct rain to roof runoff and then surface runoff. This is due to the fact that each catchment point involves a specific pollution. Surface runoff was of very poor quality since it involved in the incorporation of pollutants, first of all, from the atmosphere, subsequently from roof runoff, and finally from the surface runoff.

4.3 Proposed best practices, rainwater quality guidelines and treatment methods to improve rainwater quality.

4.3.1 Proposed best practices

It is common practice that boiling (thermal treatment), filtration, and disinfection are appropriate methods in obtaining a certain water quality. However this is an end of pipe solution. Employing a top down approach method of preventing Rainwater contamination is a more cost effective approach since pure rainwater is generally of fair quality.

Below is an approach to prevent Rainwater quality pollution.

Mapping the risks of Rainwater contamination for your system,

The system of rainwater harvesting starts by the precipitation area , followed by a catchment surface where rain collects, which is subsequently followed by a conveyance system to a collection point/ storage, this can be a water tank, a pond, dam among others, and finally a delivery system to a point of use. Identifying and avoiding the contamination sources at each of these stages can ensure rainwater of quality

Precipitation Area

The air, soil and water pollution present in a given area as a result of geology, industrial and agricultural activities in the area directly influence the quality of Rainwater. It is unfortunate that it is difficult to influence these factors but putting them into consideration when planning for any Rainwater Harvesting project can lead to positive results.

People's social factors within an area also have an important role in influencing rainwater quality. Social factors like education level, awareness of the relationship between health, water and economic development, sanitation and hygiene, planning, management and maintenance of Rainwater Harvesting systems influence rainwater quality. Therefore public awareness about water, health, sanitation and hygiene should be promoted in communities practicing Rainwater Harvesting.

Catchment surface

This is the area where rain collects; the catchment surface can be roofs, paved and unpaved surfaces. The catchment surface can be a source of contamination. Microbial contamination in RWHs is majorly as a result of pollutants from decomposing leaves, animal's faecal matter, insects and bird droppings. During the dry season, micro-organisms from accumulated dust, leaves, and animal and bird droppings are washed away during heavy pours and end up in the storage systems.

Surface runoff is vulnerable to animal and human faecal matter contamination, pesticides and fertilizers from agricultural contamination. The larger the catchment, the higher the chances of contamination due to complex management issues of large catchments.

Contamination from the catchment surface can be prevented through;

- The use of materials non-toxic for roofing for example, concrete roof, Galvanized and corrugated iron sheets. Roof materials subject to corrosion are a source of heavy metal contamination.
- Cleaning of roof surfaces before rainfall events can ensure catchment surface free from contamination from human, animal, and bird contaminates. Cutting overhanging branches over roofs.
- In case of surface runoff, planting grass and fencing off the catchment area and excavating cut off drains can improve quality. Also regulation of the activities within the catchment can bring positive results.

Conveyance

This is the means of transporting the collected rain from the catchment surface to the storage system. Rainwater transportation can be by the use of gutters and inlet pipes for Roof systems and collection and inlet canal for surface runoff.

Contamination in this case can be avoided by

- Installing a first flush system to divert the first millimeters of rainfall which have the highest pollutant load

- Installing filters at the inlet to the storage system to prevent debris, organic matter and animals from entering the storage.
- Putting a siltation basin ahead of the storage tank where all the sediments will settle before the water enters the tank. This applies for surface runoff.
- The use of materials non-toxic for the conveyance system and frequent cleaning of the conveyance system.

Storage

This is a structure or medium where the rainwater is stored. Storage systems can be on ground, above ground or sand dams. The storage structures can be made of plastic, concrete, earth, steel among others.

Contamination at this stage can be voided by

Using an adequate covering to discourage mosquito breeding, and prevent fecal contaminates and sunlight which promote algal growth from reaching the water.

Storage tanks should be provided with a hygienic abstraction for example a tap to eliminate rainwater contamination from withdrawal with dirty containers.

Treatment may be applied whenever found necessary at the point of consumption to ensure better quality and reduce the health risk.

Delivery

The final point where the use abstracts his water, this can be a tap or outlet pipe or pump.

Contamination can be avoided by,

- Putting in place a proper distribution system.
- Creating awareness through hygiene education to sensitize People about secondary contamination for example about contamination from using unclean containers.
- Closing the delivery points to avoid access from animals, since they contaminate water licking leaking taps.

- Prevent water from logging around RWHs which can enhance the breeding of mosquitoes.

4.3.2 Proposed Rainwater quality guidelines and treatment

After a review of a number of rainwater quality guidelines, (WHO, Guidelines for Drinking-water Quality, 2017, Texas Commission on Environmental Quality, 2007, United States Environmental Protection Agency, 2008, Australian Government, Department of Health, 2011). The researcher proposed guidelines and treatment methods as indicated in the table below.

Table 9: Proposed Rainwater quality parameters and treatment guidelines

Issue	**Non potable water**	**Potable Water**
Rainwater Quality Parameters	Total coliforms, E. coli, Turbidity	Total coliforms, E. coli, Turbidity
Treatment targets	Total coliforms: 500CFU/100ml E. coli : <100CFU/100ml Turbidity : <10NTU Water should be tested Annually	Total coliforms: 0 E. coli: 0 Turbidity : <1NTU Water should be tested every 3 months.
Treatment Technology	**Roof Runoff** **Pretreatment** First Flush, Roof washer, or any other appropriate pre-filtration method **Treatment** Ceramic and polypropylene Cartridge filtration with 5 micron sediment filter and periodic chlorination with household bleach **Surface Runoff** **Pretreatment** Screening Sedimentation tank, or any other appropriate pre-filtration **Treatment** Ceramic and polypropylene filtration with 5 micron sediment filter and periodic chlorination with household bleach	**Roof Runoff** **Pretreatment** First Flush, Roof washer, or any other appropriate pre-filtration method **Treatment** **Option 1** Boiling **Option 2** Filtration with 3 to 5micron sediment filter and Disinfection with UV **Option 3** Filter to Turbidity < 5NTU and disinfect using Chlorine. **Surface Runoff** **Pretreatment** Screening Sedimentation tank, or any other appropriate pre-filtration **Treatment** **Option 1**

		Filtration with 3 to 5micron sediment filter and Disinfection with UV or Boiling. **Option 2** Filter to Turbidity < 5NTU and disinfect using Chlorine.

CHAPTER FIVE CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Rainwater samples were collected for a two wet months period (during the month of May and June) from two valley tanks, one tank in Kapeke subcounty and the other in Dwaniro Subcounty, and from plastic and metallic tanks in people's home steads in the same sub counties. Also pure rain (direct rain) samples were collected in the same areas. Utmost care was taken during the sampling, storage and transportation to Water quality Laboratory.

The Analytical Laboratory results during the two months showed that the pH for pure rain ranged from 5.84 – 6.31 which is slightly acidic. While the pH ranged from 4.69 – 6.26 for roof runoff and 6.1 – 7.19 for surface Runoff.

There was 0% detection of E.Coli in pure rain, 100% detection of E.coli in roof runoff with the highest counts being 95cfu/100ml this could be as a result of contamination from accumulated dust, leaves, animal and bird droppings washed away during the raining events. There was also 100% detection of E.coli in the surface runoff with the highest counts being 235cfu/100ml, the presence of high volumes of E.Coli in the valley tanks (Surface runoff) can be attributed to livestock excreta since this is one of the major economic activity in these areas and also human excreta since during the questionnaire interview it was revealed that some cattle keepers practice open defecation.

After critically reviewing the obtained results during the study, it can be concluded that rainwater quality is not contaminant free. Generally it was observed that the mean concentration of all the heavy metals studied (Pb, Zn, and $Fe2+$) were within the acceptable limits for Uganda and WHO guidelines for drinking water with only exception of total Iron in samples from Valley tanks which was way high above the permissible limits. Concentrations of Iron from rooftop samples were relatively higher than those of pure rain samples. This can indicate that rain drops gradually erode the roof materials. But a study by Bidisha, 2015, suggests that the variation in concentration may also be as a result of environmental conditions and not totally as a result of roofing sheet contact.

All pH values were below the neutral pH with exceptions of the surface runoff water samples. The site to site variations of results in this study can be attributed to the source of the samples and the anthropogenic activities done at each site. It was also observed that rainwater contamination may not necessarily take place in industrial areas alone but also vehicular emission can contaminate rain as seen in the results. All the sampled sites were approximately 130km radius away from industrial areas but still contamination of heavy metals was detected. Generally rainwater quality is site specific representing the atmospheric characteristics of the location of the rainfall events.

Rainwater harvesting is one of the main water source for people living in Uganda’s dry lands (Cattle Corridor). Valley tanks which collect surface runoff are the main rainwater harvesting technique in this area. Majority of the people feel their rain water is of good quality something which is contrary to the findings from the rainwater quality laboratory analysis carried on samples from this area. Despite the feeling that their rainwater is of good quality, majority of the uses boil their water for only drinking purposes. From the survey none of the rainwater users in this area has ever taken their water samples for quality analysis.

Majority of the people in this area don’t have knowledge about atmospheric rain water pollution and presence of heavy metals in their water. However people in this area think that their surface runoff is at risk of contamination from bacteria from livestock waste, chemical residue from pesticides, Fertilizers from Agricultural operation, Bacteria from fecal matter, with siltation posing the greatest threat.

It is common practice that boiling (thermal treatment), filtration, and disinfection are appropriate methods in obtaining a certain water quality. However this is an end of pipe solution. Therefore a top down approach method of preventing Rainwater contamination was proposed since it is a cost effective approach based on the fact that pure rainwater is generally of fair quality.

From the analysis, it was observed overall that pathogen is the dangerous contaminant in rainwater since it has direct negative impacts on health. Therefore major precaution should be taken to eliminate pathogens from potable water. Turbidity has no health impacts but it interferers with the effectiveness of treatment. It can also lead to staining of materials, fittings and clothes exposed during washing. Putting the two factors in consideration, a combination of filters and disinfectants was recommended to provide multiple barriers and increase protection from waterborne diseases since it is hard to design a single treatment process that provides 100% protection against all pathogens.

5.2 RECOMMENDATIONS

In order to have rainwater of good quality that can be put to use for different purposes, the following recommendations should be taken care of.

Employ a top down approach method of preventing Rainwater contamination

Comprehensive Research from various locations and spanning a long period should be carried out and develop effective rainwater quality parameters to guide safe drinking water to RWHS users

Rainwater for drinking purposes, brushing the teeth and washing fruits and vegetables eaten raw should be treated before use.

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Appendices

Appendix A: CONSENT FORM

Dear Respondent,

I am a student preparing a Master in Water Science, from The Pan African University Institute of Water and Energy Sciences (Including Climate Change) (PAUWES) located on the campus of the University of Tlemcen, Algeria.

I am carrying out a research as part of my training and a requirement award of a master's Degree.

In my research, I am interested in analyzing Rainwater Quality and investigating public perceptions of Rainwater quality and use in the districts of Wakiso and Kiboga, and determine perceived risks of contaminants to harvested rainwater.

All the information collected will be used for the research purpose and the information gathered will not be passed on to any other person or institution. The questionnaire, Key Informants and focus group discussions interviews intend to collect information for purely academic purposes but not to spy on you or incriminate you in any way. Please feel totally free to provide truthful information as required and the interview will take approximately 15 minutes.

The information collected will be treated with a high degree of confidentiality and used for only research purposes.

Thanks you for the cooperation and patience

Mr. Micheal Mutambo

My Consent (Please tick to agree or disagree)

Yes……… I freely and voluntarily agree to participate in this exercise without any coercion

Signature:

Name:

Yes…….. I disagree to participate in this exercise, terminate my Questionnaire

Appendix B: Questionnaire

Please take 15 minutes of your time to complete this questionnaire. Your responses will tell us more about how central Ugandan residents feel about important Rain water quality issues.

Section 1: General Household Information

The following information is helpful to describe different groups of households. Your answers will be used for statistical purposes and will not be identified with you personally.

General Identification

1. Questionnaire ID	[ ]			
2. Respondent ID	[ ]			
3. Date of Survey (DD/MM/YYYY)	/ /			
4. Enumerator Name:				
5. Name of the head of the household				
6. Type of HH:	[ ] 1.Male headed 2.Female headed 3.Child headed			
7. Respondent's name				
8. Respondent (1=Male; 2=Female)				
9. Respondent's highest education level attained	[ ]	**Highest education level attained** 1=Primary school 2= "O" level 3= "A" level	4=Tertiary training specify years……… 5=University degree (undergraduate) 6=University degree (Post graduate) 7=Other (specify…………….)	
10. Respondent relationship to the HH	[ ] 1=HH head 2=Wife 3=Son 4=Daughter 5=Other (specify.......)			
11. Marital status of household head	[ ]	**Marital status** 1=Married 2=Widow/widower	3=Single parent 4=Divorced/separated	5=Unmarried(Not a parent) 6=Other(Specify)
12. Primary source of income of household	[ ]	**Primary source of income** 0=Non 1=crop farming 2=Cattle keeping 3=Poultry	4=Salaried employment 5=Self-employed off farm 6=Casual laborer	
11. Time interview started:	HH:	MM:		
12. Time interview ended	HH:	MM:		
13. District of survey (use code)	[ ]	District Code 1= Wakiso 2= Kiboga		
14. Name of sub-county	[ ]	14. Name of Village [ ]		
15. How would you describe the nature of your community?	[ ]	Nature of Community 1= Rural, farm 2= Rural non-farm	3= Urban (combining residential and commercial land uses and high traffic	

			intensity) 4= Mixed area (industrial & residential land uses)

Section 2: Important issues that affect Rainwater quality in communities.

1. Listed below are several aspects that impact Rain Water Quality in communities. How important is each issue to you? (Please ***tick*** for **each** concern).

Aspect	Strongly Disagree	Disagree	Moderately Disagree	Unsure	Moderately Agree	Agree	Strongly Agree
Ensuring water safety (adequate, enclosure, tight cover and proper storage)							
Water treatment before use (Boiling, filtration, disinfection, etc)							
Protecting air quality							
Protecting forests							
Managing domestic waste							
Managing faecal sludge							
Protecting wetlands							
Other (specify……………………)							

SECTION 3: RAIN WATER QUALITY.

1. What is the main source of your water?........... (1=Well, 2= Bore hole, 3= Municipal water supply, 4=Rainwater)

1. b) Do you use Rainwater?.......... (Yes=1, No=0)

2. If yes, what is the main type of your catchment? (***Please tick the appropriate choice***)

I) Tile roof ☐ II) Galvanized aluminum sheets roofs ☐

III) Iron sheets with metallic paint or other coatings roofs ☐

IV) Paved surface ☐ V) Unpaved surface ☐

VI) Others, (Specify……………………)

2. b) Where do you store your harvested Rainwater? (***Please tick the appropriate choice***)

I) Tanks made of bricks ☐ II) Metallic tanks ☐

III) Plastic tanks ☐ IV) Concrete tanks ☐

V) Earth excavations ☐ VI) tanks made of Polyethene material ☐

3. Please rate the quality of your harvested Rain water by ***ticking*** the option that matches your opinion.

Very poor	poor	Somewhat poor	unsure	Somewhat good	good	Excellent

4. What do you use your harvested rainwater for? (***Please tick appropriate choices***)

I) Drinking ☐
II) Other domestic uses ☐
III) Car washing ☐
IV) Toilet flushing ☐
V) Crop watering Irrigation ☐
VI) Livestock watering ☐
VII) Other (Specify…………………..…..) ☐

5. Does the rain water you use ever been tested for any of the following? (Yes=1, No=0)

I) Bacteria ☐
II) Heavy metals (Iron, lead, etc) ☐
III) Nitrates ☐
IV) Phosphates ☐
V) Herbicides ☐
VI) Pesticides ☐
VII) Other (Specify……………………..) ☐

5 b. If yes, what were the substances found in the water? (***Please tick appropriate choices***)

I) Bacteria ☐
II) Heavy metals (Iron, lead, etc) ☐
III) Nitrates ☐
IV) Phosphates ☐
V) Herbicides ☐
VI) pesticides ☐
VII) Other (Specify……………………..) ☐

6. Do you treat the harvested rain water before use…………………………? (Yes=1, No=0)

6.b) If yes, what are some of the methods you use to treat your harvested rainwater? (***Please tick the appropriate choice***)

I) Boiling ☐
II) Disinfection ☐
III) Pasteurization ☐
IV) Filtration ☐
V) First flush ☐
VI) Other (Specify………………) ☐

6. c) If no, why don't you treat the harvested rainwater before use?...
....
....

7. What are of the some challenges you face while using rainwater? (***Please check all that apply***)

I) Change in water colour	☐	II) Storage running dry	☐
III) Strange odor in your water	☐	IV) Other (Specify……………………)	☐

8. In which months of the year do you use Rainwater?...............................

(January=1, February=2, March=3, April=4, May=5, June=6, July=7, August=8, September=9, October=10, November=11, December=12)

9. Please rate your opinion of the **safety** of your harvested rain water by ***ticking*** the option that matches your opinion.

Very unsafe	unsafe	Somewhat unsafe	unsure	Somewhat safe	safe	Very safe

10. Please rate the following as how you feel they threaten **Rainwater quality IN THE AREA WHERE YOU LIVE**. Please ***tick*** the option(s) that matches your response.

	Strongly Disagree	Disagree	Moderately Disagree	Unsure	Moderately Agree	Agree	Strongly Agree
Heavy metals (Iron, zinc, etc.)							
Bacteria from livestock feedlots							
Chemical residue From pesticides							
Fertilizers from Agricultural operation							
Chemical residue From herbicides							
Bacteria from septic systems, toilets/faecal matter							
Silt/dust from construction Development / urban sprawl							

10. Do you have water-saving devices (low-flow faucets, toilets, showerheads, etc.) installed in your home?.................(Yes=1, No=0)

11. Do you use bottled water for drinking and/or cooking in your home?...........(Yes=1, No=0)

12. Do you use a water purification device for your tap /well /borehole water?.........(Yes=1, No=0)

12.b) If no, give your reason(s) for not treating your water

………
………………………………………………………………………………..

Section 4: Attitudes toward Rainwater quality issues. Please give your opinion of the following statements by circling the number that matches your response

Issue	Strongly Disagree	Disagree	Moderately Disagree	Unsure	Moderately Agree	Agree	Strongly Agree
There is enough awareness about rainwater quality							
There are strict Air pollution laws in my area.							
Safe and clean water ensure good health and Economic prosperity							
Industrial pollution is a threat to Rainwater quality in my area.							
Traffic pollution is a threat to my rain water quality.							
Rainwater contamination from livestock operations is a problem in my area.							
I am concerned about chemicals in my drinking water.							
It is mandatory to have a water treatment system for rainwater.							
I feel there is need to formulate the rainwater use act/policy							
Agricultural chemicals are a threat to rainwater quality in my area							
Shrubs and trees improve rainwater quality							
Rain water contamination is not a problem in my area.							
Enough attention is given to protect Rainwater quality.							

Appendix C: Budget Report

Thesis title: Analysis of rainwater quality for water supply

Prepared by Micheal MUTAMBO

Course: Msc. Water

Track: Policy

I received a research grant of 2998 USD on 8th March 2018 as per my approved research budget to aid me in preparing my master's thesis.

Summarized Budget

Purchasing light ticket from Algeria to Uganda and back to Algeria	**803.69 USD**
Water quality analysis	**1,450 USD**
Local Transport to collect water samples from the field to the Laboratory	**275.68 USD**
Purchase of Rainwater Harvesting tools	**176.76 USD**
Questionnaire exercise expenditures	**291.86 USD**
Total Expenditures	**2,997.99 USD**

Budget Notes

Money was received in the USD currency and converted in Algerian Dinners at a rate of 108 DZD to purchase the Flight ticket. The rest of the Dollars were converted to Uganda Shillings at a rate of 3700UGX and used for the rest of the thesis expenditures.

Receipts are presented in Algerian Dinners for the flight ticket and Ugandan Shillings for the rest of the thesis expenditures.

Detailed Budget

1. FLIGHT TICKET EXPENDITURES							
Item	**UNIT**		**RATE**	**RATE**	**COST**	**COST**	**BUDGET NOTE**
			DZD	**(USD)**	**DZD**	**USD**	
FLIGHT TICKET to UGANDA			81424	753.92	81424	753.92	Flight ticket from Algeria to Uganda and back from Uganda to Algeria
FLIGHT TICKET from Algiers to Tlemcen			5375	49.77	5375	49.77	Local flight ticket from Algiers to Tlemcen
Sub Total					**86,799**	**803.69**	
2. WATER QUALITY TESTS EXPENDITURES							
Parameter	**UNIT**	**No. of samples**	**RATE**	**RATE**	**COST**	**COST**	**BUDGET NOTE**
E.Coli	Cfu/100ml	19	80000	21.6216	1,520,000	410.81	Tested E.coli of all samples using Chromo Cult Agar
Color	Pt Co	18	25000	6.75676	450,000	121.62	Color was measured using DR/890 Colorimeter
Turbidity	NTU	19	30000	8.10811	570,000	154.05	Turbidity was measured using DR/890 Colorimeter
pH		19	30000	8.10811	570,000	154.05	pH was measured using a digital pH meter
Nitrates (NO3-N)	mg/l	4	40000	10.8108	160,000	43.24	Tests will be carried out both wet and dry months
Iron		19	55000	14.8649	1,045,000	282.43	NO3-N was analyzed using Cadmium Reduction method
lead	mg/l	3	55000	14.8649	165,000	44.59	Lead was analyzed using Atomic Absorption Spectrometer (Perkin

							Elmer PE 3110)
Zinc	mg/l	3	55000	14.8649	165,000	44.59	Zinc was analyzed using Atomic Absorption Spectrometer (Perkin Elmer PE 3110)
Phosphates	mg/l	8	40000	10.8108	320,000	86.49	Total Phosphorus was analyzed using Persulphate Digestion method
Total dissolved solids	mg/l	8	40000	10.8108	320,000	86.49	TDS was determined by Drying the filtrate in the oven at 105 ^{o} C
TOC		2	40000	10.8108	80,000	21.62	TOC was analyzed by Modification of walkley and black method
Sub Total					**5,365,000**	**1450.00**	
3. TRANSPORT TO COLLECT SAMPLES FROM THE FIELD TO THE LABORATORY EXPENDITURE							
Transport for six days to the field to collect rainwater samples water quality tests	Days	6	170000	45.9459	1020000	275.6757	Samples were transport for a distance of bout 200km from Kiboga to the Public health and Environmental engineering Laboratory in Kampala
Sub Total					**1,020,000**	**275.68**	
4. RAIN WATER HARVESTING TOOLS EXPENDITURE							
Item	**UNIT**	**QTY**	**RATE**	**RATE**	**COST**	**COST**	**BUDGET NOTE**
			UGX	**USD**	**UGX**	**USD**	
100 litre plastic containers fitted with a tap	piece	2	80000	21.6216	160000	43.24324	These tanks were used to harvest Roof runoff

Plastic gutters	piece	4	6000	1.62162	24000	6.486486	Gutters were used to convey rainwater to the plastic tanks
40 Litres plastic basin	piece	1	20000	5.40541	20000	5.405405	the basin was used to harvest Direct Rain
35 litre Lion star arina Cool box	piece	1	450000	121.622	450000	121.6216	The Cooler box was used to preserve the samples at a regulated temperature during transportation from the field to the Laboratory.
Sub Total					**654,000.00**	**176.76**	
5. QUESTIONNAIRE EXERCISE EXPENDITURES							
5.1 Stationary Expenditure	**UNIT**	**QTY**	**RATE**	**RATE**	**COST**	**COST**	**BUDGET NOTE**
			UGX	**USD**	**UGX**	**USD**	
Flip charts	Piece	2	15000	4.054	30,000	8.11	Flip charts were used to present to stakeholders of what the entire research was about and capture their contributions
Markers	BOXES	2	14800	4.000	29,600	8.00	These were used to note on the flipcharts and also to label the rainwater samples
Masking tape	Roll	2	5000	1.351	10,000	2.70	Masking tapes were used to hang the flip chart and also in labeling the rainwater samples
Pens	BOX	1	18500	5.000	18,500	5.00	The pens were used in the note taking and filling in the questionnaires
Stick notes	piece	4	3700	1.000	14,800	4.00	The stick notes were used to highlight emerging themes and were also used in role

							play by participants
Notebooks	piece	2	7500	2.027	15,000	4.05	Books were used in recording any extra information deemed important for the thesis as obtained in the field
Printing of Questionnaires	pecie	70	1600	0.432	112,000	30.27	70 copies of the questionnaires were printed for the interview of the exercise. Each questionnaire had 8 pages.
Sub Total					**229,900**	**62.14**	
5. 2 Transport for Identifying the targeted participates homesteads and data collection							
Car hire for identification of participants who are practicing rainwater harvesting and daily transport for data collection	Days	5	170000	45.9459	850000	229.7297	The questionnaire exercise was carried out in Kapeke and Dwaniro sub counties in Kiboga district. Kiboga district is about 200km from Kampala. There was need to identify Homesteads practicing Rainwater harvesting in those sub counties. The identified home steads were there after interviewed
Sub Total					**850,000**	**229.73**	
Grand Total (USD)						**2,997.99**	

Conclusion

The research grant was sufficient and enabled to me to do my thesis successful and indeed the long Master's journey has come to a successful end. It has been a lot of hard work, but very enjoyable. This marks the end of one trip in life but opens the door for another prominent trip. My thesis has seen the light of the day with the immense support and encouragement from **PAUWES administration** and the **African Union commission.** Thanks very much.

1. FLIGHT TICKET EXPENDITURES

Flight ticket from Algeria to Uganda and back from Uganda to Algeria

BILLET ELECTRONIQUE
RECU D'ITINERAIRE DU PASSAGER

DATE: 11 MAR 2018
AGENT: 0000
NOM: MUTAMBO/MICHEAL

YACINE VOYAGES
3 RUE BELHADJE BOUCIF
TLEMCEN
TLEMCEN
IATA : 032 10546
TELEPHONE : 213 43 272222

COMPAGNIE EMETTRICE : QATAR AIRWAYS
NUMERO DE BILLET : ETKT 157 2498367837
REFERENCE DU DOSSIER : AMADEUS: QMVJTQ, AIRLINE: QR/QMVJTQ

DE /A	VOL	CL	DATE	DEP	BASE TARIF	NVAV	NVAP	BAG	ST
ALGIERS HOUARI BOUMEDIENE TERMINAL:I	QR 1380	W	14MAR	1515	WJHQP5ZE		14SEP	45K	OK
DOHA HAMAD INTERNATIONAL				HEURE D'ARRIVEE: 2359	DATE D'ARRIVEE: 14MAR				
DOHA HAMAD INTERNATIONAL	QR 1387	W	15MAR	0755	WJHQP5ZE		14SEP	45K	OK
ENTEBBE ENTEBBE INTL				HEURE D'ARRIVEE: 1405	DATE D'ARRIVEE: 15MAR				
ENTEBBE ENTEBBE INTL	QR 1387	W	31AUG	1420	WJHQP5ZE	17MAR	14SEP	45K	OK
DOHA HAMAD INTERNATIONAL				HEURE D'ARRIVEE: 2340	DATE D'ARRIVEE: 31AUG				
DOHA HAMAD INTERNATIONAL	QR 1379	W	01SEP	0730	WJHQP5ZE	17MAR	14SEP	45K	OK
ALGIERS HOUARI BOUMEDIENE TERMINAL:I				HEURE D'ARRIVEE: 1300	DATE D'ARRIVEE: 01SEP				

A L'ENREGISTREMENT, VOUS DEVREZ PRESENTER UNE PIECE D'IDENTITE AVEC PHOTOGRAPHIE, ET LE DOCUMENT DONT VOUS AVEZ DONNE LA REFERENCE A LA RESERVATION

ENDOSSEMENTS : /C1-4 NON END/NONREF CHANGE FEE APPLIES VALID ON QR ONLY
PAIEMENT : CASH

CALCUL DU TARIF :ALG QR X/DOH QR EBB195.59QR X/DOH QR ALG195.59NUC391.18END ROE115.746700XT 1300XE20DZ1500DZ2214G4116PZ5434UL1152UG

TARIF AERIEN	: DZD	45280					
TAXES	: DZD	1300XE	DZD	20DZ	DZD	1500DZ	
	DZD	2214G4	DZD	116PZ	DZD	5434UL	
	DZD	1152UG					
SURCHARGES APPLIQUEES PAR LA COMPAGNIE	: DZD	23024YQ	DZD	1384YR			
TOTAL	: DZD	81424					

L'EMISSION CO2 MOYENNE CALCULEE EST 1416.93 KG/PERSONNE
SOURCE : CALCULATEUR D'EMISSION DE CO2 FOURNI PAR ICAO
HTTP://WWW.ICAO.INT/ENVIRONMENTAL-PROTECTION/CARBONOFFSET/PAGES/DEFAULT.ASPX

AVIS
LE TRANSPORT ET LES AUTRES SERVICES FOURNIS PAR LE TRANSPORTEUR SONT SOUMIS AUX CONDITIONS GENERALES DE TRANSPORT QUI SONT INCLUSES ICI, EN REFERENCE. CES CONDITIONS PEUVENT ETRE OBTENUES AUPRES DE LA COMPAGNIE EMETTRICE DU BILLET.
LE MOT ''BILLET ELECTRONIQUE'' DESIGNE L''ITINERAIRE/RECU EMIS PAR LE TRANSPORTEUR OU POUR SON COMPTE, TOUT DOCUMENT ELECTRONIQUE S''Y RAPPORTANT

PAGE: 1/2

Local flight ticket from Algiers to Tlemcen

Electronic Ticket Receipt

Traveler : **MUTAMBO Micheal**

Amadeus Booking ref : **WX2VCN**
Issue date : **30 AUGUST 2018**
Airline booking ref : **AH /WX2VCN**
Issuing airline : **AIR ALGERIE**
Ticket number : **124-2411565375**

Agency : POMARIA TRAVEL
3 PLACE KAIROUAN
TLEMCEN
ALGERIE

Telephone : +213 43 265353
Email : contact@pomariatravel.com
IATA : 03211574
Agent : 0000

Itinerary

From	To	Flight	Class	Date	Departure	Arrival	Resa (1)	NVB (2)	NVA (3)	Last check-in	Baggage (4)	Seat
Saturday 01 September 2018												
ALGIERS	TLEMCEN	AH6120	Y	01SEP	17:15	18:45	OK01	01SEP	01SEP		20K	
Terminal D	Terminal					Fare Basis			Y			
Operated by		AIR ALGERIE				Marketed by			AIR ALGERIE			
Equipment		Aerospatiale/Alenia ATR 72							Duration		01:30 (Non Stop)	

(1) Ok = confirmed (2)NVB= Not valid before (3)NVA= Not valid after(4) Each passenger can check in a specific amount of baggage at no extra cost as indicated above in the column baggage.

Receipt

Name	: MUTAMBO Micheal		
Ticket Number	: 124 2411565375		
Form of payment	: CASH		
Fare Calculation	: ALG AH TLM4000.00DZD4000.00END		
Air Fare	: DZD 4000		
Tax	: DZD 500DZ	DZD 20DZ	DZD 855YB
Total Amount	: DZD 5375		
Issuing Airline and date	: AIR ALGERIE 30 August 2018		

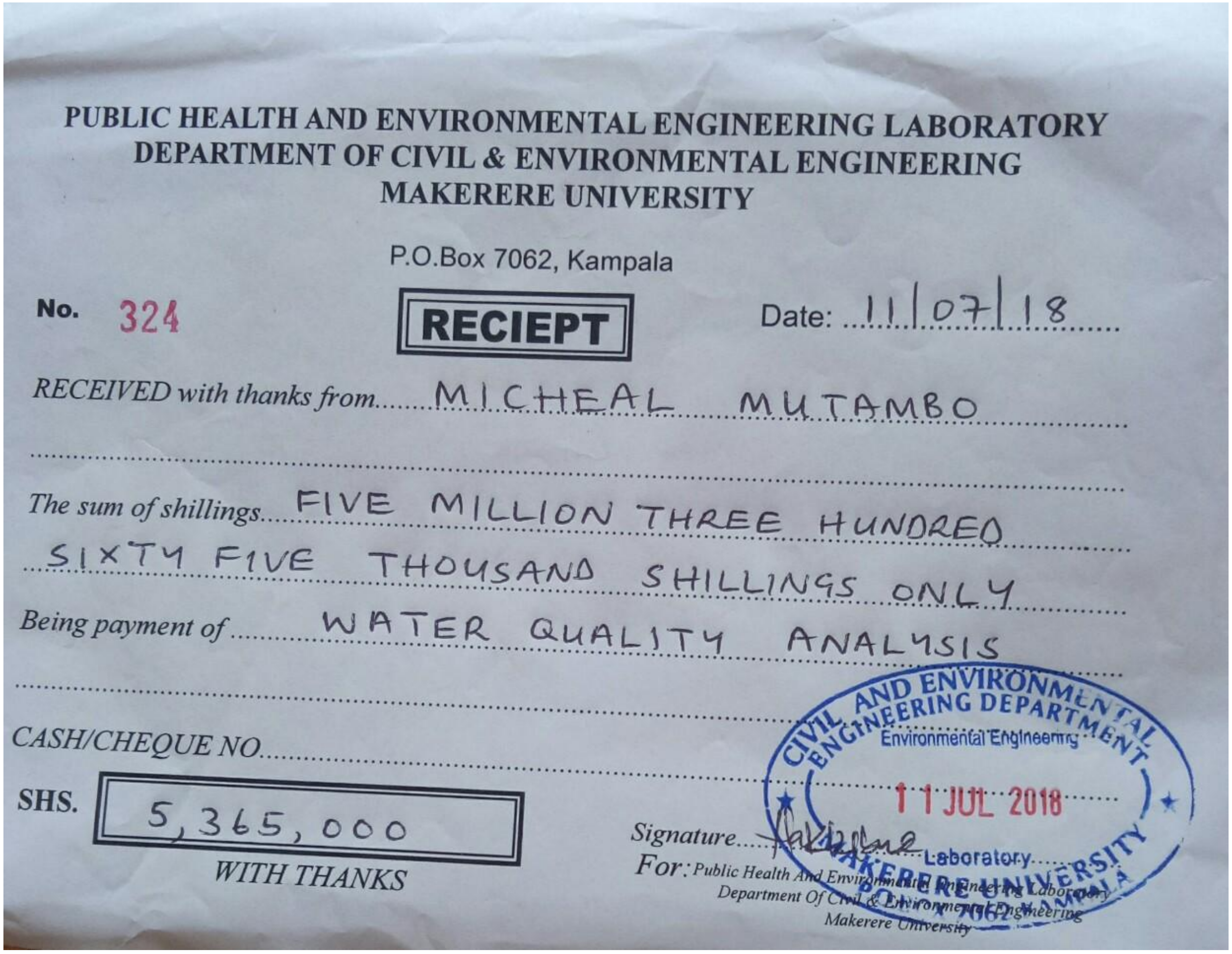
AGENCE DE VOYAGES
S.N.C POMARIA TRAVEL
03, Place Kairaouan - TLEMCEN
Tél: 043. 27. 79. 04 et 043. 26. 53. 53
Fax : 043. 26. 49. 71

The fare that applies on the date of purchase is only valid for the entire itinerary and the specific travel dates mentioned on the ticket.

Our company wishes you a very pleasant trip.
This document establishes the creation of your electronic ticket(s) in our computer systems.
For further information, please contact us.

Carriage and other services provided by the carrier are subject to conditions of carriage, which are hereby incorporated by reference. These conditions may be obtained from the issuing carrier. The itinerary/receipt constitutes the passenger ticket for the purposes of article 3 of the Warsaw convention, except where the carrier delivers to the passenger another document complying with the requirements of article 3. Passengers on a journey involving an ultimate destination or a stop in a country other than the country of departure are advised that international treaties known as the montreal convention, or its predecessor, the warsaw convention, including its amendments (the warsaw convention system), may apply to the entire journey, including any portion thereof within a country. For such passengers, the applicable treaty, including special contracts of carriage embodied in any applicable tariffs, governs and may limit the liability of the carrier. These conventions govern and may limit the liabilityof air carriers for death or bodily injury or loss of or damage to baggage, and for delay.

2. WATER QUALITY TESTS EXPENDITURES



PUBLIC HEALTH AND ENVIRONMENTAL ENGINEERING LABORATORY
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
MAKERERE UNIVERSITY

P.O.Box 7062, Kampala

No. 324 **RECIEPT** Date: 11/07/18

RECEIVED with thanks from MICHEAL MUTAMBO

The sum of shillings FIVE MILLION THREE HUNDRED SIXTY FIVE THOUSAND SHILLINGS ONLY

Being payment of WATER QUALITY ANALYSIS

CASH/CHEQUE NO.

SHS. 5,365,000

WITH THANKS

Signature [signature] Laboratory

For: Public Health And Environmental Engineering Laboratory
Department Of Civil & Environmental Engineering
Makerere University

CIVIL AND ENVIRONMENTAL ENGINEERING DEPARTMENT
Environmental Engineering
11 JUL 2018
MAKERERE UNIVERSITY

Rainwater quality results for all samples

MAKERERE UNIVERSITY

COLLEGE OF ENGINEERING DESIGN, ART AND TECHNOLOGY

CIVIL AND ENVIRONMENTAL ENGINEERING DEPARTMENT

Public Health andEnvironmental Engineering Laboratory

Laboratory Results

Roof Runoff Results

	Dates							
	18/05/2018		28/05/2018		11/6/2018		26/06/2018	
Parameters	PT1	PT2	PT1	PT2	PT1	PT2	PT1	PT2
E.Coli (Cfu/100ml)	36	56	11	95	15	0	55	6
Turbidity (FAU)	4	0	1	1	5	1	0	2
pH (upH)	5.61	5.47	5.3	5.87	4.99	4.69	5.48	6.26
Color (PtCo)	99	30	46	51	102	31	25	97
Iron (Fe2+) (mg/l)	0.11	0.12	0.1	0.06	0.13	0.25	0	0.09

Surface runoff Results

Parameters	Dates							
	18/05/2018		**28/05/2018**		**11/6/2018**		**26/06/2018**	
	VT1	VT2	VT1	VT2	VT1	VT2	VT1	VT2
E.Coli (Cfu/100ml)	135	70	175	105	40	120	235	90
Turbidity (FAU)	40	985	28	1020	25	1024	30	998
pH (upH)	6.8	6.97	6.6	7.1	6.1	7.19	6.99	7.14
Color (PtCo)	280	9342	305	10240	293	9080	291	10500
TOC (mg/l)	0.08	0.021	-	-	-	-	-	-
Iron (Fe2+) (mg/l)	0.78	2.7	0.71	2.65	0.8	2.72	0.63	2.68
COD	32	41	35	38	49	29	28	40
TDS (mg/l)	163	2730	156	2598	124	2272	130	2393
N total (NO3-N) (mg/l)	-	-	-	-	0.4	9.3	0.6	5.55
P total (mg\l)	0.16	4.472	0.2	4.793	0.22	5.452	0.218	5.21

Pure rainwater Results

Parameters	Dates		
	28/05/2018	11/6/2018	26/06/2018
E.Coli (Cfu/100ml)	0	0	0
Turbidity (FAU)	6	10	14
pH (upH)	6.31	5.84	5.95
Color (PtCo)		188	145
Iron (Fe^{2+}) (mg/l)	0.05	0.04	0.09
Zinc (mg/l)	0.0157	0	0
Lead (mg/l)	0.14	0.1	0.12

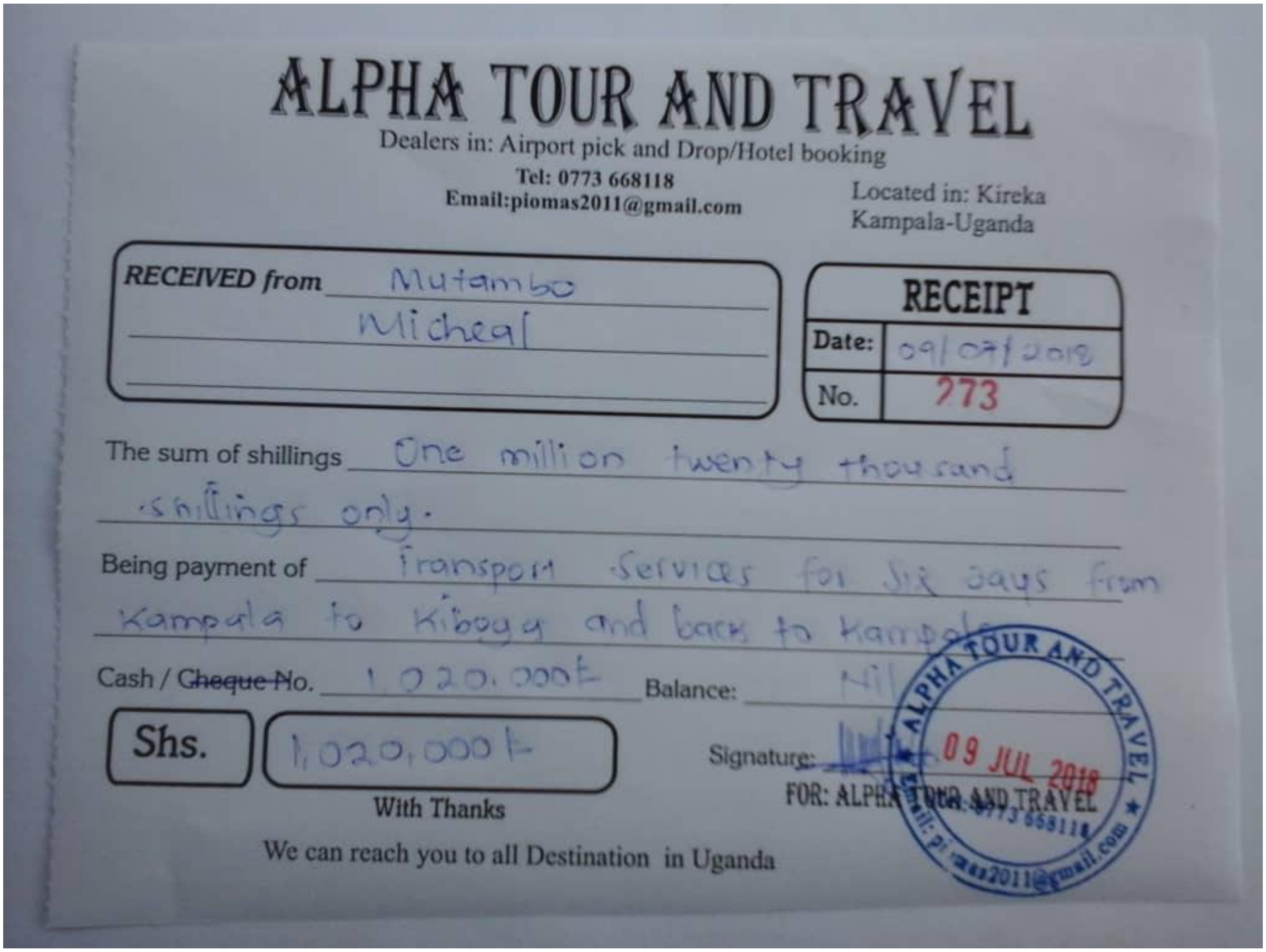
Approved by;

…Nakazibwe…………

Rita Nakazibwe
For: Laboratory In-charge

CIVIL AND ENVIRONMENTAL ENGINEERING DEPARTMENT
Environmental Engineering
11 JUL 2018

3. TRANSPORT TO COLLECT SAMPLES FROM THE FIELD TO THE LABORATORY EXPENDITURE



ALPHA TOUR AND TRAVEL

Dealers in: Airport pick and Drop/Hotel booking

Tel: 0773 668118

Email:piomas2011@gmail.com

Located in: Kireka

Kampala-Uganda

RECEIPT

Date: 09/07/2019

No. 273

RECEIVED from Mutambo Micheal

The sum of shillings One million twenty thousand shillings only.

Being payment of Transport services for six days from Kampala to Kiboga and back to Kampala

Cash / ~~Cheque No.~~ 1,020,000/= Balance: Nil

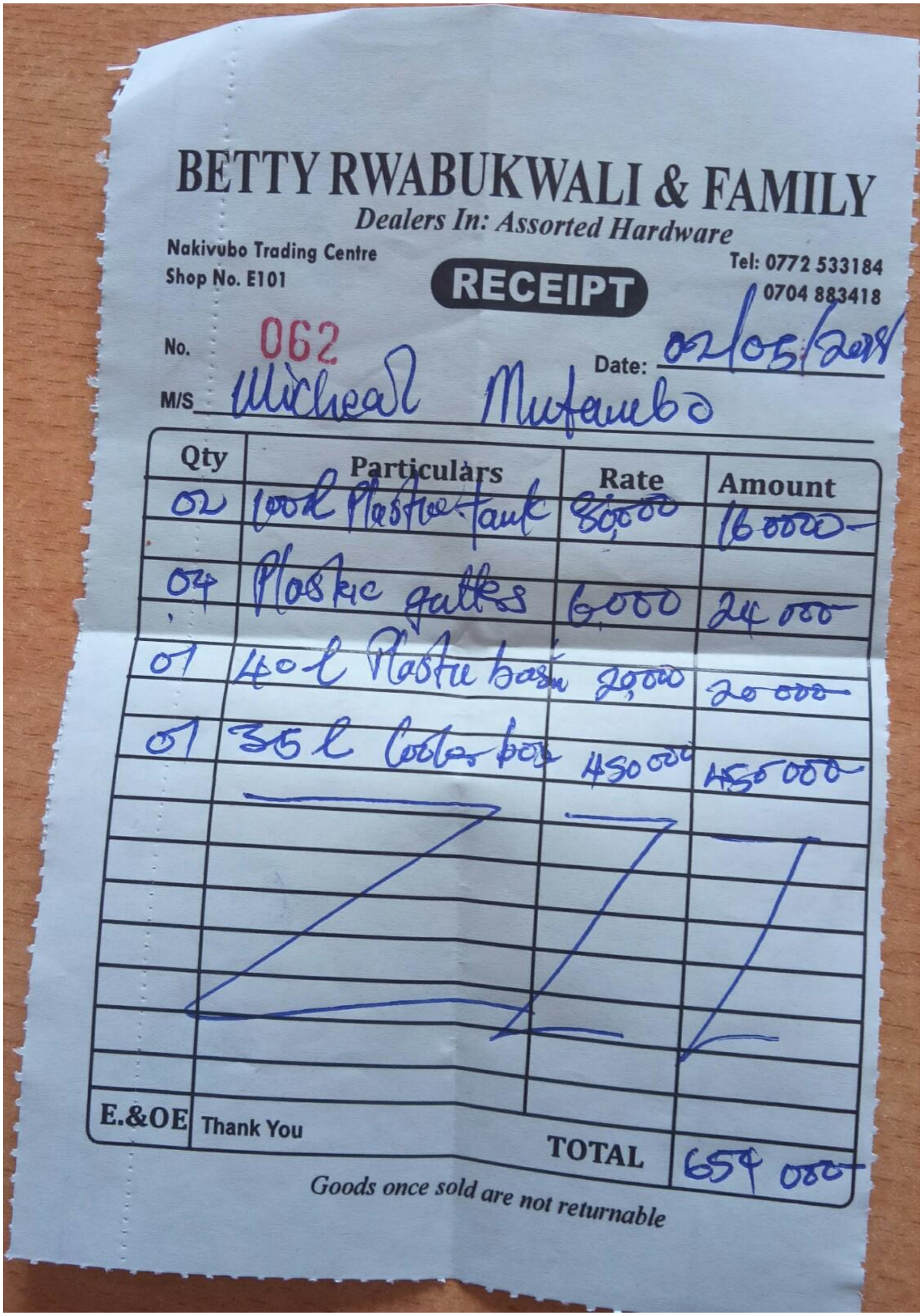
Shs. 1,020,000/=

Signature: FOR: ALPHA TOUR AND TRAVEL

With Thanks

We can reach you to all Destination in Uganda

4. RAIN WATER HARVESTING TOOLS EXPENDITURE



BETTY RWABUKWALI & FAMILY

Dealers In: Assorted Hardware

Nakivubo Trading Centre
Shop No. E101

RECEIPT

Tel: 0772 533184
0704 883418

No. 062

Date: 02/05/2018

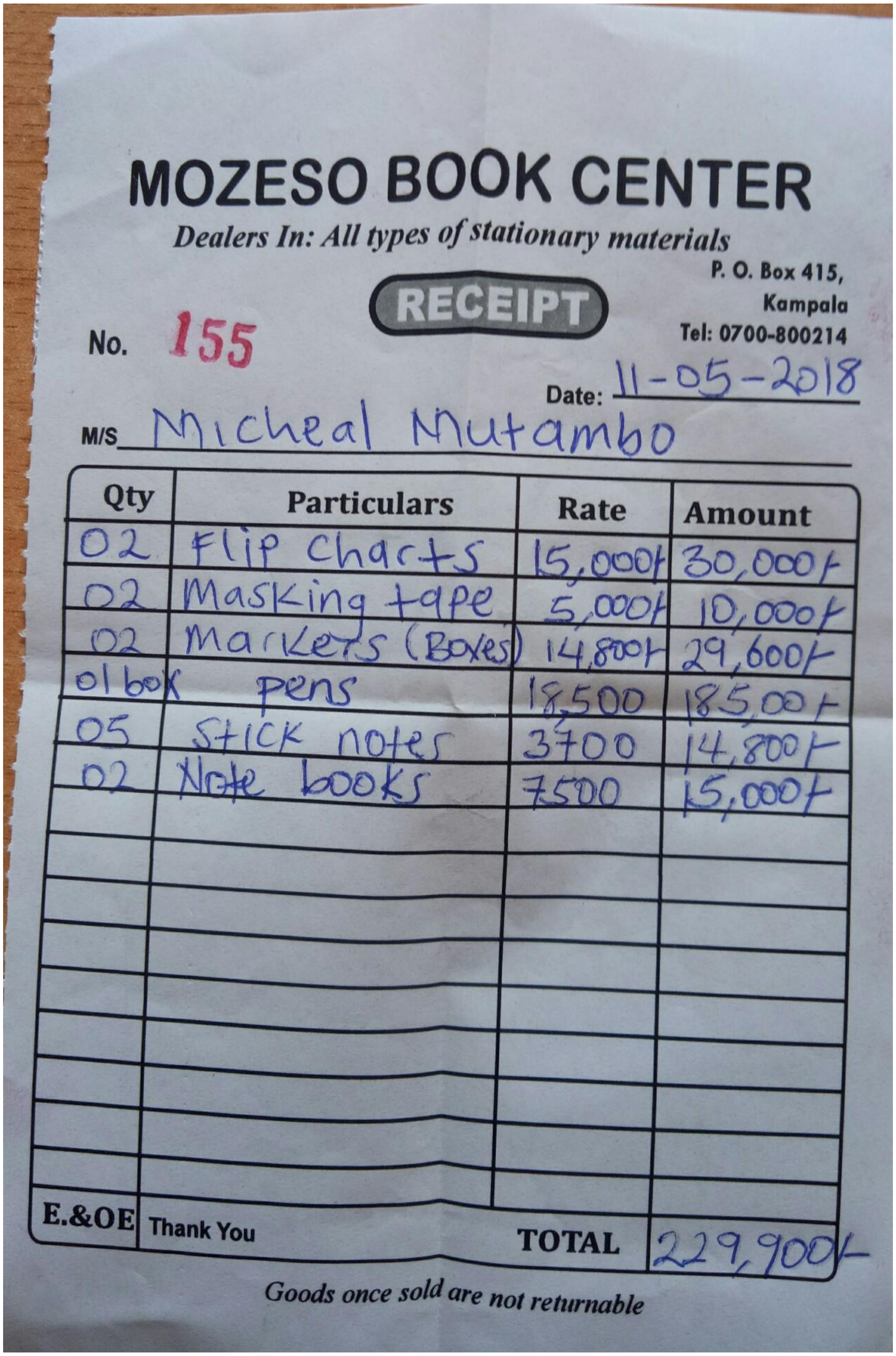
M/S Michael Mufambo

Qty	Particulars	Rate	Amount
02	100l Plastic tank	80,000	160000-
04	Plastic gutters	6,000	24 000
01	40l Plastic basin	20,000	20 000
01	35l Cooler box	450 000	450 000
E.&OE	Thank You	TOTAL	654 000

Goods once sold are not returnable

5. QUESTIONNAIRE EXERCISE EXPENDITURES

5.1 Stationary expenditures



MOZESO BOOK CENTER

Dealers In: All types of stationary materials

P. O. Box 415,
Kampala
Tel: 0700-800214

RECEIPT

No. 155

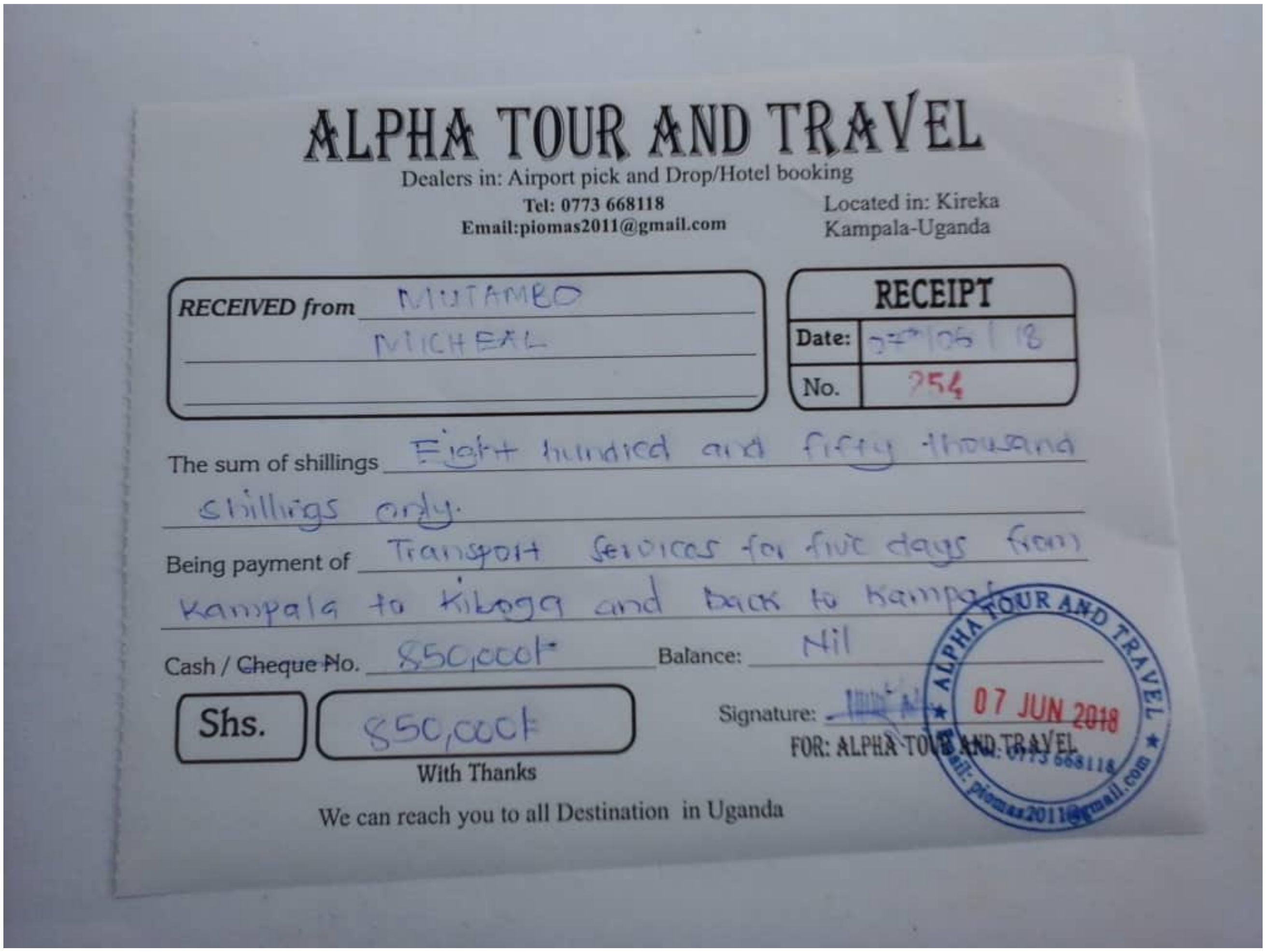
Date: 11-05-2018

M/S Micheal Mutambo

Qty	Particulars	Rate	Amount
02	Flip Charts	15,000/-	30,000/-
02	Masking tape	5,000/-	10,000/-
02	Markers (Boxes)	14,800/-	29,600/-
01 box	pens	18,500	185,00/-
05	Stick notes	3700	14,800/-
02	Note books	7500	15,000/-
E.&OE	Thank You	TOTAL	229,900/-

Goods once sold are not returnable

5. 2 Transport for identifying targeted participates' homesteads and data collection



ALPHA TOUR AND TRAVEL

Dealers in: Airport pick and Drop/Hotel booking

Tel: 0773 668118
Email:piomas2011@gmail.com

Located in: Kireka
Kampala-Uganda

RECEIPT

RECEIVED from MUTAMBO MICHEAL

Date: 07/06/18

No. 254

The sum of shillings Eight hundred and fifty thousand shillings only.

Being payment of Transport services for five days from Kampala to Kiboga and back to Kampala

Cash / ~~Cheque No.~~ 850,000/= Balance: Nil

Shs. 850,000/=

With Thanks

Signature:

FOR: ALPHA TOUR AND TRAVEL

ALPHA TOUR AND TRAVEL 07 JUN 2018

We can reach you to all Destination in Uganda

Annexes

Introduction letter to obtain field data

THE REPUBLIC OF UGANDA

KIBOGA DISTRICT LOCAL GOVERNMENT

Office of the Chief Administrative Officer
P.O. Box I
KIBOGA

E-Mail: Caokiboga@Gmail.Com
Telephone: 0392-766616

Ref: KBG/HRM/164/4

12th June 2018

The Senior Assistant Secretaries
Kapeke and Ddwaniro sub-counties
Kiboga District Local Government

INTRODUCTION OF MICHAEL MUTAMBO

Mr. Mutambo Michael is a male Ugandan, aged 28 years preparing a Master in Water Science from The Pan African University Institute of Water and Energy Sciences located on the campus of the University of Themcen, Algeria.

He is requesting to collect data for his master thesis in your sub-County. In his research, he is interested in analyzing Rainwater Quality and investigating Public perceptions of rain water quality and use.

Data collection will be through the use of a questionnaire attached herewith and collection of Rainwater samples from people's storage tanks and will be taken to Makerere University water quality laboratory for analysis.

Kindly render him necessary assistance to enable the success of his research.

FOR CHIEF ADMINISTRATIVE OFFICER
KIBOGA DISTRICT
12 JUN 2018
SIGNATURE:

Nalumansi Rose
For: Chief Administrative Officer

Copy to:
The District Chairperson, Kiboga
The RDC, Kiboga
The DPC, Kiboga Police Post
The OC Station, Kapeke /Ddwaniro Police Posts
The Sub-County Chairperson, Kapeke/Ddwaniro Sub-counties