EFFECTIVENESS OF CHARCOAL FILTERS INTEGRATED WITH *Moringa oleifera* SEED EXTRACTS IN PURIFYING WATER FROM UNPROTECTED SOURCES OF KAPSERET DIVISION, UASIN GISHU COUNTY, KENYA

BY

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DECLARATION

Declaration by the candidate

This thesis is my original work and has not been presented for a degree in any other university. No part of this thesis may be reproduced without the prior written permission of the author and/or University of Eldoret.

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This thesis has been submitted for examination with our approval as University Supervisors.

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DEDICATION

This thesis is dedicated to my family, friends and colleuagues at the University of Eldoret for their unending support throughout the studies.

ABSTRACT

Moringa oleifera Lam (MO) is a pan tropical, multipurpose tree whose seeds contains high quality edible oil (up to 40% by weight) and water soluble proteins that act as effective coagulants for water and wastewater treatment. Chemical coagulation may leave certain residuals such as aluminum that raises health concerns. Besides, most rural residents are not able to read instruction manuals on the dosage rates of the chemical coagulants. It is in this light that this study was carried out with the objective of determining the effectiveness of *Moringa oleifera* integrated charcoal filter in improving surface water quality based on the physicochemical and biological parameters. Laboratory jar test procedures was used for coagulation studies on experimental runs using actual stream water from the five sampling streams in Kapseret. Water extracts of *Moringa oleifera* seeds and Aluminium sulphate were applied to stream water treatment sequence comprising coagulation–flocculation–sedimentation. Samples of water treated with *Moringa oleifera* were later filtered over charcoal before analysis was done.. A raw water sample from each of the sampling points acted as a control. The study was laboratory based using actual stream water from various unprotected sources. Statistical analysis was done using One-way Analysis of variance (ANOVA) to assess whether significant ($p < 0.05$) variations existed among the treatments. Tukey's test was carried out to verify the significance of differences among the means. In this study, the most significant finding of using ***Moringa oleifera*** seed extract as coagulant is the reduction from initial reading of turbidity at 40 mg L^{-1} with 85.55% of removal efficiency where the lowest turbidity was achieved even with smaller doses used compared to aluminum sulphate at 50 mg L^{-1} with 78.72.%. The pH and conductivity of the stream water were not affected by the *Moringa oleifera* seed extract. Nitrate and sulphate were not influenced by the *Moringa oleifera* seed extract except phosphate which recorded a slight increase. Turbidity of raw water samples was significantly reduced by 97.52% in a combined treatment involving *Moringa oleifera* seed powder and charcoal filter with a p-value of 0.005. The pH of the purified water was within the WHO (2005) recommended range of 6.0-8.5. The effect of the combined treatment of *M. oleifera* and charcoal filter on sulphate, phosphate and nitrate was significant with p-values of 0.001, 0.001 and 0.025 respectively.Total coliforms was significantly reduced by 8.39% (p=0.014) while fecal coliforms was significantly reduced by 99.23% with a p-value of 0.003 in a combined treatment of *Moringa oleifera* and charcoal filter. The integrated treatment also reduced the conductivity and BOD of river water by28.68% and 21.25%, respectively. These studies have shown that *M. oleifera* integrated charcoal filter system can be very effective in treatment of surface water from streams.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ANOVA	-Analysis of Variance
APHA -	American Public Health Association
BOD	- Biological Oxygen Demand
COD	- Chemical Oxygen Demand
DO	- Dissolved oxygen
ELDOWAS	-Eldoret Water and Sewerage Company
FAO	-Food and Agricultural Organization
FC	-Fecal coliforms
MO	-*Moringa oleifera*
MPN	-Most probable number
NTU	-Nephelometric Turbidity Units
SOCs	-Synthetic organic compounds
TC	-Total coliforms
WASH	-Water sanitation and health
WHO	-World Health Organization
W/V	-Weight per Volume

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CHAPTER ONE

INTRODUCTION

1.1 Background Information

One of the most common problems afflicting people throughout the world is inadequate access to clean water for domestic purposes. Problems associated with water sanitation and hygiene (WASH) are expected to deteriorate in the coming decades, with water scarcity occurring globally, even in regions currently considered water-rich (Montgomery and Elimelech, 2007). Addressing these problems calls out for a tremendous amount of research to be conducted so as to identify robust new methods of purifying water at an affordable cost and that is within the reach of those in poor resource settings and with less energy, while at the same time minimizing the use of chemicals that may impact on the environment (Shannon *et al*., 2010).

According to theUnited Nations (UN), Kenya is classified as a chronically water-scarce country (Mogaka, 2006). The Kenyan population stands at about 44 million people out of which about 17 million (43%) do not have access to clean water (World Bank, 2010). This is further compounded by the climatic conditions of Kenya that vary from tropical along the Kenyan coast of the Indian Ocean to arid in the interior that leaves two thirds of the country either semi-desert or desert land where water scarcity problem is a reality (Lea, 2010).

Other reports indicate that access to safe water supplies throughout Kenya is about 59% and access to improved sanitation is estimated to be 32% (Marks & Davies, 2012). Consequently, there still remains an unresolved need in rural and urban areas for both water and sanitation (Montgomery *et al.,* 2007). Furthermore, Kenya faces challenges in water provision with erratic weather patterns in the past few years

causing droughts and water shortages that compounds the problem (Ngaira, 2009). Kenya also has a limited renewable water supply and is classified as a water scarce country (Rijsberman, 2006). In addition, most of the urban poor Kenyans only have access to polluted water which causes cholera epidemics and multiple other diseases that affect health and livelihoods. Despite the critical shortage of clean water in Kenya's urban slums, there is a large rural to urban discrepancy in access to clean water in Kenya. According to World Bank (2010), slightly less than half of the rural population has access to water, as opposed to the urban population where 85 percent have access to safe water. Due to continued population growth, it has been estimated that by the year 2025, Kenya's per capita water availability will be 235 m^3 / year, about two-thirds less than the current 650 m^3 (Wafula, 2010).

It is important to mention that clean water and sanitation are among the most powerful preventive activities in the field of medicine for reducing child mortality rates (Cairncross et al., 2010).However, most water providers and national governments have traditionally focused on implementation of large, centralized treatment systems which unfortunately do not serve rural areas, where populations are dispersed and the proportion served is less than half that in urban areas (Montgomery and Elimelech, 2007).

1.2 Statement of the Problem

Most water sources in developing countries are unsafe for domestic use because they are contaminated with chemicals and microbial agents due to poor management of wastes or are inadequately treated (Cheesbrough, 2006). This has contributed to approximately 80% of all illness encountered in public health (Ashbolt, 2004). Harsh climatic conditions related to drought in the recent past have further aggravated the

issue of water scarcity in Kenya (Liebhardt, 2010). This therefore calls for enhanced utilization of the scarce water resources.

The water sources used by humans and animals in Kapseret Division of Uasin Gishu County do not receive any form of treatment to reduce microbial and chemical pollutants. The area is a peri-urban setup with an increasing population owing to outward expansion of Eldoret town and rural-urban migration. Major water sources in the area include rivers, shallow wells and streams. These sources are usually unprotected and therefore exposed to pollution. Direct fetching and use of water from these water sources by local residents therefore compromise hygienic standards due to the presence of microbes and chemicals (Eschol *et al.,* 2009). This practice is evident in settlement areas of the current study area. The cost of conventional methods of water purification using aluminium sulphate and calcium hypochlorite is prohibitive for mostdeveloping countries and beyond reach of most rural folks and the urban poor. Besides, chlorine resistant pathogens such as *Cryptosporidium* spp are unaffected (Meinhardt*et al.,* 1996). Furthermore, dirt and other organic matter bind with chlorine, limiting its effectiveness. Therefore, a reliable, low cost point of use water treatment intervention to be used at household level by the residents is required to improve on the water quality.

This study therefore aims at assessing the effectiveness of using *Moringa oleifera* seed extract and charcoal filter, as an alternative to chlorine, in reducing the pollutant load in water sourced from unprotected rivers in Kapseret.

1.3 Justification of the Study

The two most commonly used primary coagulants are aluminium and iron (III) salts (Okuda *et al.,* 1999). The use of alum and iron salts is not economically viable in some developing countries because of the high cost and low availability of chemical

coagulants (Schultz and Okun, 1983). The use of chlorine bleach to disinfect water has several limitations. One drawback is that chlorine resistant pathogens such as *Cryptosporidium* spp. are unaffected (Meinhardt*et al.,* 1996).

There is evidence that simple, acceptable, low-cost interventions at the household and community level are capable of dramatically improving the microbiological quality of household stored water and reducing consumers' risks of diarrheal diseases and death (Sobsey, 2002).

An alternative to chlorine bleach as water disinfectant is use of locally available plant extracts and filters for local water treatment. A commonly used plant for this purpose is *Moringa oleifera.* It is considered to be one of the world's most useful trees in implementing low-cost water purification technologies (Sengupta*et al.,* 2010). Many studies have been done on the performance of *Moringa oleifera* seeds as a primary coagulant in water treatment (Ghebremichael, 2004; Muyibi and Alfugara, 2003). *Moringa oleifera* can reduce turbidity in low-turbid water of 21.5-49.3 NTU to 2.7 NTU, water of medium turbidity of 51.8-114 NTU to 2.9 NTU and that of high turbidity of 163-494 NTU to 1.4 NTU (Muyibi and Alfugara, 2003). Therefore *Moringa oleifera* will be a good alternative in treating waste water.

1.4 Objectives of the study

1.4.1 General objective

The main objective of the study was to evaluate the effectiveness ofusing *Moringa oleifera* seed extract as a coagulant and wattle stem charcoal as filter material in purification of stream water from unprotected sources in Kapseret.

1.4.2 Specific objectives

The specific objectives of the study were to:

i. Evaluate the treatment efficiency of ***Moringa oleifera*** seed extracts and Aluminum sulphate on water quality in terms of turbidity removal in drinking water.

ii. Determine the treatment efficiency of charcoal filter in improving stream water quality for drinking.

iii. Determine the combined effect of *Moringa oleifera* seed extract and wattle stem charcoal in improving stream water quality for drinking.

1.5 Hypotheses

Ho There is no significant difference between *Moringa oleifera* seed extract and Alumimum sulphate on coagulation of suspended solids in stream water.

Ho Charcoal filter has no significant effect on physico-chemical and microbial properties of stream water.

Ho *Moringa oleifera* seed extract integrated with charcoal filter has no significant effect on the physico-chemical and microbial properties of stream water.

CHAPTER TWO

LITERATURE REVIEW

2.1 The Importance of Water

Potable water is an essential component or need for a healthy living. Safe water, adequate sanitation and proper nutrition are essential health needs to be met in the developing and the developed nations (Sobsey and Bartram (2003), Aulia (1994) and Lester & Sterritt(1988)). These needs contribute to reduced diseases and increased health (Sobsey and Bartram, 2003).

Water plays an important role in supporting life. If contaminated, it also has a great potential of contributing to the global burden of diseases and illnesses (Moe & Rheingans,2006). Water from unprotected sources is usually turbid and contaminated with microorganisms that cause many diseases. Water-borne diseases are one of the main problems in developing countries (Amagloh & Benang, 2009). Serving the world with adequate safe drinking water and sanitation is an important prerequisite to hygienic safety, prosperity and political stability (Bartram and Balance, 1996) reported that Over one billion people have no access to safe drinking water globally, while 2.6 billion lack adequate sanitation leading to deaths of 1.8 million people every year from water related diarrheal diseases (Moe & Rheingans,2006). Among this population it has been reported that 90% of children under the age of five years, are mainly from developing countries.The conventional method of water purification using aluminum sulphate (alum) and calcium hypochlorite exerts pressure on nations' over-burdened financial resources since they are imported thereby making treated water very expensive in most developing countries and beyond the reach of most rural folks. The use of alternative, non-conventional, relatively cheap, sustainable and

readily available water purification methods could be the most suitable intervention for developing countries.

2.2 Domestic water contamination

Domestic water is that which is used for domestic purposes including drinking, cooking and personal hygiene (Kabede, 1978).River water drawn for human consumption and general household use can be highly turbid particularly during rainy season. River silt is churned into suspension and run off from fields and other surfaces carries solid material, bacteria and other microorganisms into the river. It is of paramount importance to remove as much of this suspended matter as possible prior to a disinfection stage and subsequent consumption. This, generally, can be achieved by the addition of coagulants to the raw water, within a controlled treatment sequence (Pritchard *et al.*, 2010).

2.2.1 Sources of domestic water contamination

Microbiological contamination of water has been the world's biggest concern since 1920s up to 1960s (Myhrstad and Haldorsen, 1984). Microbes that contaminate water include bacteria, viruses and protozoa. Fecal coliform bacteria are indicator organisms of human fecal contamination and it occurs when water is contaminated by the same (Wright *et al*., 2004). They are a group of bacteria that include many strains such as *Escherichia coli* (Chesbrough, 2006 and Shannon, 2003). They are usually in large quantities than some pathogenic microbes that may be present in water (Olivieri*et al.,* 1977). They live in the soil and are found in large numbers in the gastro-intestinal tract of animals especially man (Macdonald *et al*., 1999).

2.2.2 Description of fecal coliforms

Fecal coliforms normally grow in the large intestines of humans and are present in large numbers in the feces of humans (Mburu*et al.,* 2008). They are also found in the

waste of warm blooded animals such as birds and mammals and may find their way into water bodies through fecal discharges or seepage especially in poorly designed disposal facilities (Mburu*et al.,* 2008). These fecal coliforms organisms are able to ferment lactose at 44.5^{o}C within 48 hours (Nzung'a *et al.,* 2013).

Fecal coliforms are the standard by which microbial contamination of domestic water source is determined, and whose presence is definitive proof of water contamination by fecal matter (Sugden, 2004 and Cheesbrough, 2006). Human feces are a primary source of fecal bacteria in water (Olivieri*et al.,* 1977). Fecal coliforms enter the water supplies from the direct disposal of wastes into streams or lakes or run-offs from wooded areas, feedlots, septic tanks and sewage plants into streams or ground water (Franceys*et al*., 1992). Bacteria from these sources can enter wells that are open at the land surface or do not have watertight casings or caps and other unprotected water sources (Jorge *et al*., 2010).

Microbial contaminants in drinking water are normally introduced through oral means and bacterial coliforms are of primary concern in terms of fecal contamination of drinking water sources (Tebbut, 1992). Fecal coliforms can also enter domestic water source through run-offs or backflow of water from contaminated source, (Sha'Ar *et al*., 2002).

2.3 Water purification methods

2.3.1 Filtration

Most, if not all, waterpurification systems contain a filterstage. These filter out large solids fromwater. Filters can also remove smaller particles likesilt and suspendedsolids; dissolved ions and some filters catch bacteria andviruses. Oneof these filtration methodsisthe sand filter. There aretwo types of sand filters: a rapid sand filter and aslow sandfilter. Rapid sand filters filter waterthrough sand, butspeed

up the process byusingchemicals as well. Slow sand filters consist ofalayer of finegrain sand supported on alayer of gravel, thetopmost layerconsistingofa biofilm (alayer ofbiological activity called aschmutzdecke),bacteria fungi anda rangeof aquaticlarvaethat havebeen caught there. As thisbuilds up, microorganisms help to metabolizeorganic material in thewater, cleaning it. Slow sand filters requireamoreor less continuous flowofwaterto avoid dryingoutthebio layerandto ensureacontinuous flowof nutrients to support themicroorganisms in thebio layer(Adank *et al.*, 2016).

2.3.2 Chemical disinfection

Themost common chemical used to disinfect wateris Chlorine (Cl). Chlorine is a very effective disinfectant and also provides some residual disinfection; it remains in water to stop recontamination.Chlorineis morethan 3 times more effectivein disinfecting waterthan the equivalent concentrationofbromine and 6 timesmore effectivethan iodine (Koski, *et al* 2000).Drawbacks of usingchlorinecan be strangetaste and smellof water (usuallyassociatedwith shock- chlorination with much higherconcentrations), aswellasaslight risk of naturallyoccurring organic compounds combiningwith chlorine to form carcinogenic compounds. However,the WHOstates that that health risks associated with the productsaremuch smaller than risks associated with inadequate disinfection (Amy *et al*, 2000).

2.3.3 Sedimentation

This is process in whichcontaminants that areheavierthan watersink to thebottom of abasinand the wateristhen led outofthe basin abovethesediment layer.

2.3.4 Flocculation

Elements such as Aluminium (Al) can beused in aprocess called flocculation. Flocculation is aprocesswhere colloids comeout of suspensionin a solute, such as water.Aluminium, which is positivelycharged attracts negativelycharged bacteriaand

viruses,allthis then sinks to the bottom (Sedimentation) and can then befiltered out (Monis *et al*., 2014).

2.3.5 Stabilization

Highlycontaminated waste-wateris left in ponds wherenatural biological processesremovepathogens (Samuelsson, 2011).The ponds areusuallybuilt in aseries ofat least three;anaerobic, facultative and aerobic. The first, anaerobicpond is 2-5 m deep andwaterstays there for1-7 days only.Here anaerobic bacteria transform organic carboninto methane,removingup to 60%of biologicalactivity. Effluent is then ledto a facultativepond,1-2.5 mdeep andadetention timeof 5-30 days (Adank *et al.*, 2016).

A combination ofprocesses happen; anaerobicbacteriadigest sludgeon thebottom and closerto the surfaceaerobicprocesses work, receivingoxygenfrom natural diffusion, algae photosynthesis and wind-mixing (Adank *et al.*, 2016). The facultativepond removesup to a further 75 %of biological activity.In both thesestages, sedimentation occurs andeffluent is led to thenext pond from abovethe bottom sludge. Thelast, aerobic, pond is often called the finishing, maturation orpolishingpond, because it finishes thework off. Maturationponds can bebuilt in series ofmorepondsforbetter pathogen removal. Ofthe threeponds in thestabilization process, thematuration pond is the onethat removes actual pathogens (Monis *et al*., 2014).

2.3.6 Reverse osmosis

A reverseosmosisfilteris based on the chemicalprocess of osmosis. This means that when two solutions areseparated byasemi-permeablemembrane, solvent will tend to flow through the membranefrom an areaof low concentrationto an areawith highconcentration. The membranewilllet through the solvent but not the bigger particles of thesolute, forcingthe solvent to flowinstead ofthe solutein a normal solution.In reverseosmosis, pressureis applied to theside ofthemembranewith high

concentration;usually2-17bars dependingon the concentration ofthe solution.This forces the solvent (water) from the areaof high solute concentration through themembraneto theareawith low(orno) concentration. Eventuallyall thesolute is caught ononeside, the reverseof theoriginal osmosisprocess. Reverse osmosisis often used in desalination and to removeotherdissolved ions (Helmenstine, 2011).

2.4 Moringa oleifera

Moringa oleifera is a small to medium-sized deciduous tree that develops a swollen underground rootstock. It produces large elongated capsules, each containing numerous seeds. *Moringa oleifera* has been grown since ancient times and is now widely cultivated and naturalized throughout the tropical and subtropical world (Ramachandran*et al.*, 1980). The plant is drought resistant, preferring regions with a wet/dry climate. It can, however, be grown in a wide range of habitats on a variety of soils (Abou-Zeid and Salama, 2014).

Moringa oleifera is most productive in drier seasons and the leaves usually turn yellow in rainy seasons. Since every part of this tree is valuable in nature for several uses globally, it is facing a lot of exploitations from humans (Beentje, 1994).

2.4.1 Moringa oleiferaTaxonomy

Kingdom:	Plantae
Division:	Tracheophyta
Subdivision:	Spermatophytina
Class:	Magnoliopsida
Order:	Brassicales
Family :	Moringaceae
Genus :	Moringa
Species:	*Moringa oleifera*

Common name: Drumstick tree

Local names: Lorisiancho (Ilchamus); Chepyakwai (Tugen); Chotwa (Pokot).

2.4.2 General Distribution of *M. Oleifera*

Moringa oleifera is a vegetable tree which is grown in Africa, Central and South America, the Indian subcontinent, and South East Asia (Figure 2.1).

Figure 2.1: General Distribution of *M. oleifera*

(Source; www.worldagroforestry.org)

2.4.3 Biophysical information and uses of *M. oleifera*

Moringa oleifera does well in an altitude of 0-1,000 m, with a mean annual temperature of 12.6 to 40 ^{0}C. The plant also requires a mean annual rainfall of at least 500 mm.The plant is adapted to a wide range of soil types but does well in well drained clay or clay-loam without prolonged water logging. It prefers a neutral to slightly acidic soil reaction, but it was been introduced more than a quarter a century ago with success in the Pacific where the pH is as high as 8.5 (Ramachandran*et al.*,

1980). The plant responds well to mulch, water and fertilizer.Growth is stunted in areas with a high water table (Agyepong, 2009).

Moringa oleifera is an extremely fast-growing tree, and within 1-3 months after planting it is able to attain a height of 2.5 m. (Ojiako&Adikuru 2011). *Moringa* trees are commonly grown for their leaves, and topping-out("pinching" or cutting off some of the top growth) is useful to keep an abundant supply of leaves, pods and flowers within easy reach (Ojiako&Adikuru 2011). The considerable potential of various uses and products associated with the plant has actively promoted its cultivation in many developing countries of the world (Orwa *et al*., 2009).

Different parts of the plant have potential use as food, fodder, medicine, fuel wood and fertilizer (Foidl*et al*., 2001).The seeds are probably the most useful part of the plant, containing a significant percentage of high quality oil (Rashid *et al*., 2008). In the recent past, the large-scale cultivation of *Moringa oleifera* has been suggested as a potential source of biofuel (Razon , 2009).

The leaves of the plant (Figure 2.2) provide a good source of protein, vitamins A, B and C and minerals such as calcium and iron, which are used similar to spinach (Oduro *et al*., 2008). Further, the plant is an excellent source of the sulphur-containing amino acids, methionine and cystine, which are often in short supply (Mensah*et al*., 2012). *Moringa oleifera* leaves are also used as livestock feed for feeding camels and cattle (Makkar& Becker, 1996). The plant's silviculture, involving regeneration by cuttings, coppicing and pollarding, keeps flowering on and off most parts of the year, which provides nectar to honey bees for a long period (Price, 1985). The soft and light wood of the plant is acceptable firewood for cooking but makes poor charcoal (Kumar *et al*., 2012). Its bark, when beaten, produces a fibre used to make small ropes and mats (Maroyi, 2006).

A study on the production of rayon grade pulp from *M. oleifera* by a pre-hydrolysed sulphate process in India shows that it is suitable as a raw material for the production of high alpha cellulose pulp for use in cellophane and textiles (Foidl*et al*., 2001). The wood is very soft and light and is useful only for light construction work. When the tree is injured, the stem exudes a gum that is used in calico printing, as a condiment, and for stomach and bladder ailments. The mucilaginous gum has a bland taste and belongs to the hog series of gums (Maroyi, 2006). The plant's bark is used for tanning hides and its wood yields a blue dye. Oil extracted from the mature pods (oil of Ben) is yellowish, non-drying, good keeping qualities but eventually turns rancid. It is used as a lubricant, in cosmetics and perfumes, and to some extent is a substitute for whale sperm-oil (Foidl*et al.*, 2001).

Moringa seeds are effective against skin-infecting bacteria, *Staphylococcusaureus* and *Pseudomonas aeruginosa* (Price, 1985). They contain the potent antibiotic and fungicide terygospermin.

Plate 2.2: *Moringa oleifera* leaves

2.5 Use of *Moringa oleifera* and Aluminum sulphate in water treatment

River water drawn for human consumption and general household use can be highly turbid particularly during the rainy season. River silt is churned into suspension and

run off from fields and other surfaces carries solid material, bacteria and other microorganisms into the river. It is of paramount importance to remove as much of this suspended matter as possible prior to a disinfection stage and subsequent consumption. This, generally, can be achieved by the addition of coagulants to the raw water, within a controlled treatment sequence (Sutherland *et al*., 1994).

In many developing countries, chemical coagulants, such as aluminium sulphate and synthetic poly-electrolytes are usually unavailable (Sutherland, 2000). Moringa tree seeds, when crushed into powder, can be used as a water-soluble extract resulting in an effective natural clarification agent for highly turbid and untreated pathogenic surface water (Mangale, 2012). Besides improving water drinkability, this technique reduces water turbidity (cloudiness) resulting in water being both aesthetically as well as microbiologically more acceptable for human consumption (Lea, 2010). The application of this low cost *Moringaoleifera*seeds is recommended for eco-friendly, nontoxic, simplified water treatment for rural and peri-urban people living in extreme poverty. In ancient Egyptian cultures, carbon filters were used for medical purposes and as a purifying agent (Cheremisinoff*et al.*, 1980).

Using natural materials to purify water is a technique that has been practiced for centuries and of all the materials that have been used, seeds of Moringa plant have been found to be one of the most effective (Sutherland *et al*., 1990). Studies have been conducted since the early 1970's to test the effectiveness of *Moringa* seeds for treating water (Doerr& Staff, 2005). These studies have confirmed that the seeds are highly effective in removing suspended particles from water with medium to high levels of turbidity.

Moringa oleifera seeds can be applied to treat water on two levels, acting both as a coagulant and an antimicrobial agent (Ferreira *et al.*, 2011). It is generally accepted

that *Moringa* plant works as a coagulant that leads to the formation of "flocs" that settle at the bottom of water (Maheshwari & Parihaar, 2013). The antimicrobial aspects of *Moringa* plant continue to be investigated (Doerr& Staff, 2005). While there are on-going research work being conducted on the nature and characteristics of these components, it is accepted that treatments with *Moringa* solutions remove 90-99.9% of the impurities in water (Gambhir*et al*., 2013). A viable alternative to the chemical coagulants is natural coagulant (Anwar *et al*., 2007). *Moringa* seed pods are allowed to dry naturally on the tree prior to harvesting. The mature seeds are readily removed from the pods, easily shelled and then may be crushed and sieved using traditional techniques such as those employed for the production of maize flour (Joshua *et al.,* 2013). The crushed seeds' powder, when mixed with water, yields a solution (Folkard*et al.*, 1995).To treat surface water, the equivalent weight of seed powder required to make up a crude extract solution is dependent upon the turbidity (Lea, 2010).

Moringa o*leifera* derived coagulants offers several advantages over conventional coagulants such as aluminium sulphate (Folkard& Sutherland, 1995). This includes its activity being maintained over a wide range of influent pH values with no pH correction is required. Natural alkalinity of the raw water also remains unchanged following coagulation i.e. no addition of alkalinity is required. Sludge production is also greatly reduced and is essentially organic in nature with no aluminium residuals sludge volumes are reduced by a factor of up to 5 (Ndabigengesere*et al*., 1998). Coagulants that occur naturally are regarded as safe in terms of health for human while synthetic coagulants, especially aluminum salt, has probability inducing Alzheimer's disease (Egbuikwem & Sangodoyin, 2013). This is supported by other

studies where rising health risks was mentioned from drinking the water with residual aluminum left in it such as neurodegenerative illness (Fitria *et al*., 2014).

2.6 Charcoal filters in water treatment

Charcoal filters consist of either compressed charcoal/carbon block which is the best type of charcoal filter since it can remove chemicals and lead. It is however easily clogged, hence should be used with sediment pre-filter. Charcoal filter can also comprise of granular charcoal. This is cheaper, but water can flow around the granules without being treated. Powdered charcoal is a very fine dust useful for spot cleaning larger bodies of water, but is messy and can pass through some filters and be consumed. Activated carbon filters for home-based water treatment typically contain either granular activated carbon or powdered carbon block. Both forms of filters are effective; however, carbon block filters generally have a higher contaminant removal ratio.

2.6.1 History of charcoal filters

Charcoal filters have been used for several hundred years and are considered one of the oldest means of water purification (Cheremisinoff*et al.,* 1980). Historians have shown evidence that carbon filtration may have been used in ancient Egyptian cultures for medical purposes and as a purifying agent (LeChevallier & McFeters, 1990). The first recorded use of a charcoal filter to purify potable water on a large scale occurred in 19th century England (LeChevallier & McFeters, 1990).Currently, carbon filters are used in individual homes as point-of-use water filters, groundwater remediation, landfill leachate, industrial wastewater and, occasionally, in municipal water treatment facilities.

2.6.2 Mechanism of action of Charcoal filters

The charcoal filter functions primarily by the process of adsorption. Adsorption, which signifies a surface interaction between dissolved species and the charcoal, is distinct from absorption, which essentially means “to soak up” or “to take into.” In water treatment, contaminants diffuse into char pores (absorption) where they bind to charcoal surfaces (adsorption).

The porosity and large surface area of charcoal provides a multitude of reactive sites for the attachment of dissolved compounds. These reactive sites can bind non-problematic dissolved organic compounds as well as targeted hazardous contaminants. Background dissolved organic matter, present in all natural waters, can occupy sites on charcoal surfaces and thereby exclude contaminants of concern. This is called “fouling.” Fouling in charcoal filters is mitigated by upstream unit processes that act to remove a substantial portion of background dissolved organic matter from the source water before it encounters the charcoal. The principle is to achieve a high level of treatment prior to the charcoal filter, in order to “save the carbon” for removal of targeted problematic dissolved compounds that make it through the previous treatment steps.

In treatment system described here, the charcoal filter functions as a post-coagulation adsorber. The charcoal filter is placed after the *Moringa* seed treatment in order to target specific components of background organic matter (for example, compounds that cause undesirable tastes, odors, or appearance) or synthetic organic compounds (SOCs) such as pesticides, pharmaceuticals, fuel compounds, and others that are not well removed by the preceding unit processes.

2.6.3 Efficiency of charcoal filters

The two most important factors affecting the efficiency of activated carbon filtration are the amount of carbon in the unit and the amount of time the contaminant spends in contact with it. The more the carbon used the better. Similarly, the lower the flow rate of the water, the more time that the contaminants will be in contact with the carbon, and the more absorption that will take place. Particle size also affects removal rates.The effective lifetime of the charcoal filter media depends upon the quality of the charcoal, as well as the characteristics of the source water and efficacy of upstream treatment steps.

2.7 Physicochemical and microbial parametersof water

The water quality parameters of greater concern are pH, Biological Oxygen Demand (BOD), nitrates, phosphates and conductivity (Larsdotter, 2006). In addition, bacteriological parameters are also used as indicators of water quality. The most commonly used bacteria forms are fecal coliforms, total coliforms, *E. coli* and fecal *Streptococcus.*

2.7.1 Physicochemical parameters

2.7.1.1 Potential Hydrogen (pH)

Potential hydrogen (pH) is the measure of a solution's acidity or alkalinity (Tebbut, 1992). In water, a small number of water (H_2O) molecules will dissociate into hydrogen ions (H^+) and hydroxide ions (OH^-). Other compounds entering the water may react with these, leaving an imbalance in the numbers of hydrogen and hydroxide ions (Sharon *et al.*, 1997). When more hydrogen ions react, more hydroxide ions are left in solutions and the water becomes basic. However, when more hydroxide ions react, more hydrogen ions are left and the water becomes acidic.

pH is a measure of the number of hydrogen ions and thus a measure of acidity or alkalinity (Abdul-Razak *et al.,* 2009).

Water with extremely high or low pH is lethal (Trevett *et al*., 2004). The pH values of drinking water should be 7 and any deviation either negative or positive from this neutral value affects the quality of drinking water. Water with high or low pH affects human health.

2.7.1.2 Turbidity

Turbidity is a measure of how particles suspended in water affect water clarity. It is an important indicator of suspended sediments and erosion levels (Sharon *et al.,* 1997). Typically it will increase sharply during and after rainfall, as a result of sediments being carried into the water sources hence high turbidity (Abdul-Razak *et al.,* 2009). Elevated turbidity will also raise water temperature. Suspended silt and clay, organic matter, and plankton can contribute to turbidity. Organic matters originating from domestic and industrial waste could serve as good environment for bacteria to grow. Besides, microorganisms and algae can also cause cloudiness in the water. When *M. oleifera* was added to the sample and followed by rapid stirring, the resulting cationic protein from *M. oleifera* was distributed to all parts of the liquid and then interacted with the negatively charged particles that caused dispersed turbidity. Such interactions disturb the forces that stabilize the particles, so that it can bind to small particulates to form precipitate by process of coagulation (Nkurunziza*et al.*, 2009). Turbidity is usually measured in Nephelometric Turbidity Units (NTU). This is an optical measurement, where a light beam is transmitted through the water sample, and the amount of scattered and absorbed light is detected (Hammer and Hammer Jr., 2004). The World Health Organisation allows agricultural water with turbidity below 5 (WHO, 2004).

2.7.1.3 Conductivity

This is a measure of the capability of a solution such as water in a stream, well, spring or river to pass an electric current. This is an indicator of the concentration of dissolved electrolyte ions in water (Abdul-Razak *et al.,* 2009). It doesn't show the specific ions in the water. However, significant increase in conductivity may be an indicator that polluting discharges have entered the water source (Sharon *et al*, 1997). High conductivity will result from the presence of various ions including nitrates, phosphates and sodium. The basic units of measurements for conductivity are microm hos per centimeter (μmhos/cm) or microsiemens per centimeter (μs/cm). It's a measure of the inverse of the amount of resistance that an electric charge meets in travelling through the water (Abdul-Razak *et al.,* 2009). Distilled water has a conductivity ranging from 0.5 to 3μs/cm; while most streams range from 50 to 1500 μs/cm.The higher the value of dissolved solids, the greater the amount of ions in water (Bhatt *et al.,* 1999). Increasing levels of conductivity and cations are the products of decomposition and mineralization of organic materials (Abida &Harikrishna, 2008). Conductivity in water varies widely due to variation in solubility of minerals in different geographic regions.

2.7.1.4 Dissolved chemicals

2.7.1.4.1 Nitrates

Nitrogen is abundant on earth, accounting for about 78% of the total air. Most plants cannot use it in this form, but legumes and blue green algae have the ability to convert nitrogen gas into nitrates (NO_{3-}), which can be used by plants (Tahir & Rasheed, 2008). Plants use nitrates to build protein, and animals that eat plants also use organic nitrogen to build protein. When plants and animals die or excrete waste, this nitrogen is released into the environment as NH_4^+ (Ammonium) (Tahir &

Rasheed, 2008). The ammonium ions are then oxidized to nitrites (NO_2^-) and then nitrates (NO_3^-) by bacteria. Nitrogen in this form is common in freshwater aquatic ecosystems. Nitrates enter underground water from natural sources like decomposition of dead plants and animals as well as human sources such as fertilizer and sewage effluents (Tebbut, 1992).

2.7.1.4.2 Phosphates

Phosphate (PO_4^{-3}) is a compound derived from phosphorous and oxygen. Phosphorous is required in small quantities for plant growth and metabolic reactions in animals and plants (Pant *et al*., 2001).The main sources of phosphates include sewage, detergents, fertilizer, animal wastes and disturbed land. Phosphates do not cause human health risks except in extreme levels. Phosphates are measured in mg/l (Pant *et al*., 2001).

2.7.1.4.3 **Sulphates (SO_4^{2-})**

Even though there is no health-based guideline proposed for sulphate, intake of high sulphate levels has gastrointestinal effects. It is recommended that health authorities be notified of sources of drinking water that contain sulfate concentrations in excess of 500 mg/L. The presence of sulphate in drinking-water may also cause noticeable taste and may contribute to the corrosion of distribution systems (WHO, 2008).

Dissolved sulphate (SO_4^{2-}) can be derived from the dissolution of sulphate minerals; oxidation of pyrite and other forms of reduced sulphur; oxidation of organic sulfides in natural soil processes; andanthropogenic inputs, i.e. fertilizers (Grasby*et al*., 1997). Biological oxidation of reduced sulphur species to sulphate, increase in concentration. Discharge of industrial wastes and domestic sewage in waters tends to increase its concentration (Trivedi and Goel, 1984). The sulphate data is used in determining applicability of different water types for their public and industrial applications.

2.7.2 Microbiological parameters

2.7.2.1 Fecal coliforms

This coliform group has been used as an indicator of contamination by human and warm-blooded animals (Cheesbrough, 2006). Fecal coliforms normally grow in the large intestines of humans and are present in large numbers in the feces of humans (Mburu *et al.,* 2008). They are also found in the waste of warm blooded animals such as birds and mammals and may find their way into water bodies through fecal discharges or seepage especially in poorly designed disposal facilities (Mburu*et al.,* 2008). These fecal coliforms organisms are able to ferment lactose at 44.5^{o}C within 48 hours (Jamieson *et al.,* 2003).

The presence of fecal coliform bacteria in water bodies indicates the possible detection of pathogenic organisms that can cause waterborne diseases like diarrhea, cholera and others (Sugden, 2004). Contamination of surface water, shallow wells and rivers is a challenge that is caused by inadequate sewage disposal systems facilities (Sobsey, 2003). Coliforms also enter water in hand-dug wells through backflows from contaminated ground and containers (Eschol *et al.,* 2009). The guidelines for water quality as per WHO is shown in table 2.1 below (World Health Organization, 2004).

Table 2.1: WHO Guidelines on Water Quality Values

Parameter	WHO Guideline value (Maximum allowable)	General and Health Effects
Ph	Desirable-6.5 Permissible-8.0	- Affect mucous membrane - Bitter taste - Corrosion - Affect aquatic life
Turbidity	Desirable ≤ 5NTU	-Affects water clarity -Affects water odour
Conductivity	Desirable- 0.5-3.0 µs/cm Permissible- 3000 µs/cm	-Nil
Nitrate	Desirable-45mg/l Permissible-100mg/l	-Blue baby disease (methemoglobinemia) -Algal growth
Sulphate	Desirable-200ml/l Permissible-400mg/l	Taste effect, laxative effect, gastrointestinal irritation
Phosphate	-	Algal growth
Total coliform	Desirable 0 coliforms/100ml Permissible 10 coliforms/100ml	Gastrointestinal illness
Fecal coliforms	Nil/100ml	Gastrointestinal illness
BOD	Desirable 5mg/l	Affects aquatic life

2.7.2.2 Total coliforms

The coliform group includes a number of genera and species of bacteria which have common biochemical and morphological attributes that includes gram negative, non-spore forming rods that ferment lactose in 24-48 hours at 35^0C (Jamieson *et al.*, 2003). Most coliforms also produce enzyme β-D galactosidase that can be detected with a color-forming reagent (Mallin*et al*., 2000). The group generally comprises the genera *Klebsiella*, *Enterobacter* and *Citrobacter*(Mallin*et al*., 2000). Identification or

detecting these bacteria in water is a definitive indication of water contamination by feces or inefficient water treatment systems (Eschol *et al.,* 2009).

2.7.2.3 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand is the amount of dissolved oxygen needed by aerobic biological organisms in a water body to break down organic materials present in a given water sample, at a given temperature over a specific period (Tahir & Rasheed, 2008). While dissolved oxygen (DO) tells how much oxygen is available, a BOD test tells how much oxygen is being consumed (Tebbut, 1992). High BOD levels indicates decline in DO, because the oxygen that is available in the water is being consumed by the bacteria leading to the inability of aquatic organisms to survive in the river (Pathak and Limaye, 2011).

BOD is determined by measuring the dissolved oxygen level in a freshly collected sample and comparing it to dissolved oxygen level in a sample that was collected at the same time but incubated under specific conditions for certain number of days (Jamieson *et al.,* 2003). The difference in the oxygen readings between the two samples is the BOD. The standard units for BOD are mg/l. Natural and unpolluted water has a BOD of 5 mg/l or less while raw sewage may have BOD levels ranging from 150-300 mg/l (Jamieson *et al.,* 2003).

Most of the studies undertaken earlier have involved a single stage water treatment process involving either coagulation or filtration. Either of the processes will have a limitation. It is with this consideration in mind that an integrated water treatment system involving coagulation of suspended particles by *Moringa oleifera* seed extract and a subsequent filtration over a charcoal filter was designed. The study aims at leveraging on the positive aspects of either of the processes so as to achieve maximum water purification levels.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was conducted in Kapseret division, Uasin Gishu County, Kenya (Figure 3.1). It comprises of Simat, Chepkatet and Lemook locations (Figure. 3.2). The region covers an area of 148.30 square kilometres and lies between longitude 34 degrees 50' east and 35 degrees 37' west and latitude 0 degrees 03' south and 0 degrees 55' north. The topography of the region is relatively flat. The local elevation varies from about 2100 metres above sea level at the airport to more than 2700 metres in nearby areas (7000–9000 feet). It receives an annual rainfall ranging between 900-1200mm. This occurs between March and September with two distinct peaks in May and August. The dry spells begin in November and end in February while temperatures range between 8.4 and 26^{o}C but these features are changing probably due to climate change (Luke*et al*., 2011). According to the 2009 Population and Housing Census, the total population of Kapseret stood at 31,030.

The area is a peri-urban setup with an increasing population owing to outward expansion of Eldoret town and rural-urban migration. The main economic activity in the area is agriculture with dairy farming and horticulture being the major economic earners. Consequently, during the rainy season, most of the surface run off washes off animal wastes and farm fertilizers and other chemicals into the water sources. Major water sources in the area include streams, shallow wells and springs. These sources are usually unprotected and therefore exposed to pollution.

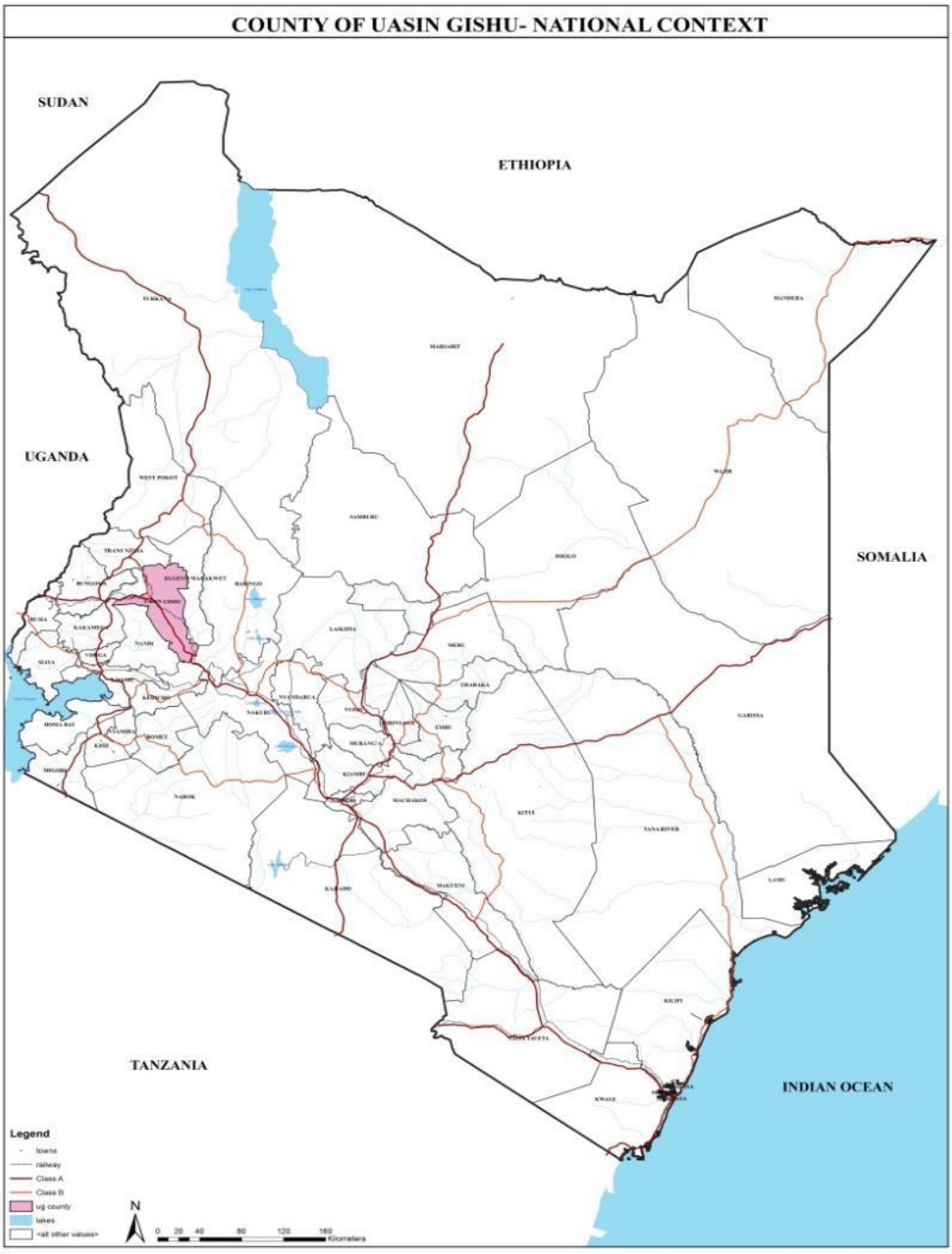

Plate 3.1: Map of Kenya showing the location of Uasin-Gishu County

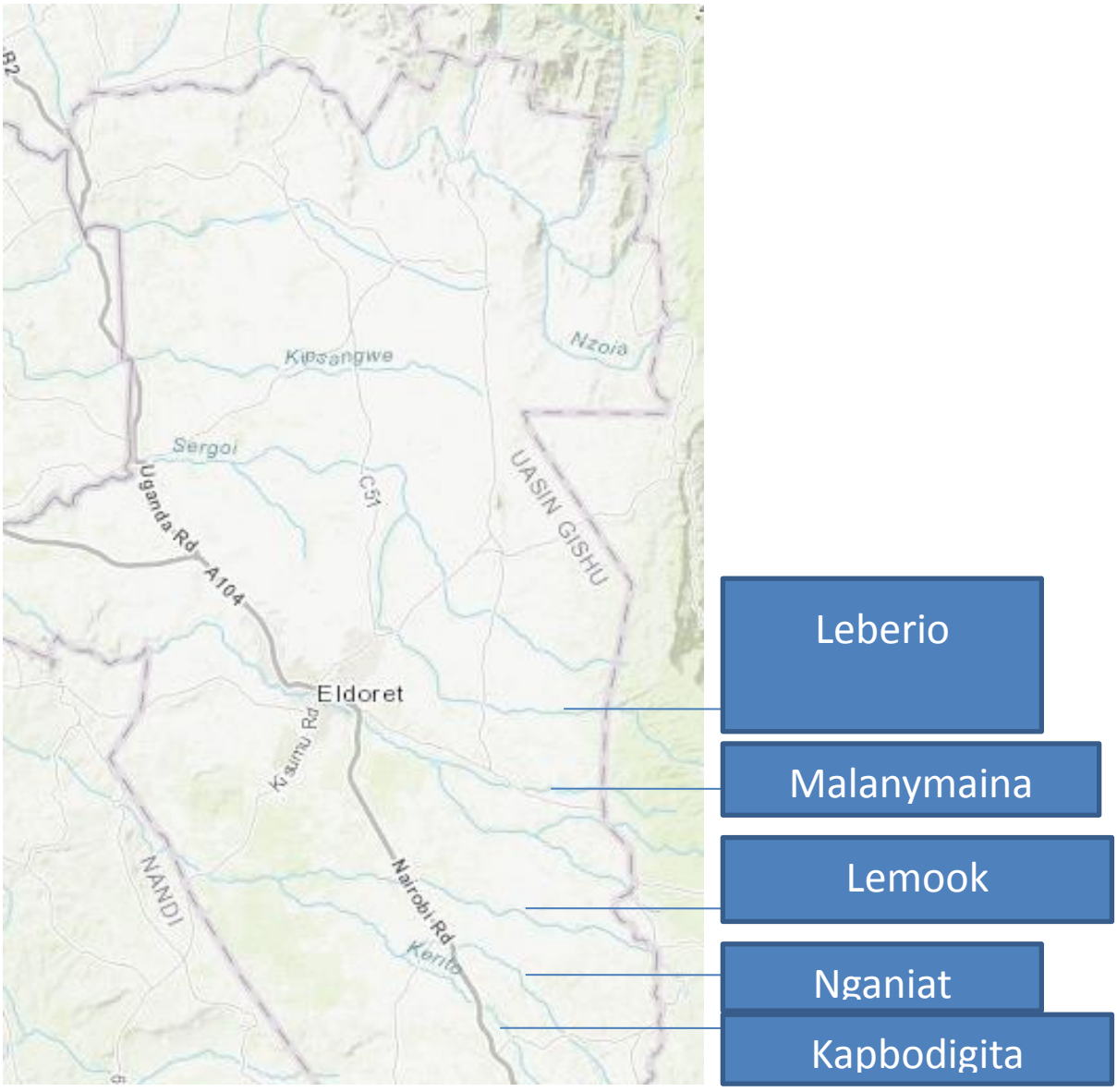

Plate 3.2: Map of Uasin Gishu showing location of streams under study.

3.2 Assessment of the coagulation abilities of *Moringa oleifera* and Aluminum sulphate (Alum).

3.2.1 Treatment of Sample Containers

Glass sample bottles (2000 ml)were sterilized in an autoclave at 121 ^{0}C for 15 minutes at 121 kPa.

3.2.2 Preparation of Coagulants

There were two types of coagulants used in this study, a naturally occurring coagulant, which is ***Moringa oleifera*** and a synthetic type of coagulant that is aluminum sulphate (laboratory grade).

Fully matured *Moringa oleifera* seeds were collected from Marigat forest. The seeds were air-dried in direct sun for a week (Appendix 1, Plate 1). Seeds showing no signs of discoloration, softening or extreme desiccation were used (Ndabigengesere and Narasiah, 1998). The seed kernels were ground to a fine powder of approximate size of 425 µm to achieve proper solubilization of active ingredients in the seed. Distilled water was added to the powder to make (1, 2, 3, 4 and 5) %w/v suspension. (For example, 1 %w/v is prepared by 1g of *M. oleifera* powder in 100ml water). The suspension was vigorously shaken for 30 min using a glass rod stirrer to promote water extraction of the coagulant proteins and this was then filtered through paper (Whatman No. 1). Fresh solutions were used to prevent any ageing effects (such as change in pH, viscosity and coagulation activity). Solutions were shaken vigorously before use (Ndabigengesere and Narasiah 1998; Jahn, 1988).

The aluminum sulphate which acts as synthetic coagulant was used for comparison in terms of treatment efficiency with ***Moringa oleifera***. Aluminum sulphate was also grounded into fine powder using pestle and mortar before being used in the study.

3.2.3 Sampling and Sample Preparation

Sampling procedures described by American Public Health Association (APHA, 1995) were followed. Approximately one and half litres of sample was fetched from each of the five streams. A total of 5 different samples with three (3) replicates were taken from Leberio, Malanymaina, Lemook, Nganiat and Kapbodigita.Sampling sites represented 30% of all the streams in the study area. These sites were randomly

chosen to represent an even distribution of the streams in the study site. in 2000 ml glass sample bottles. Water samples were collected by immersing and opening the bottle caps under water. Once collected, the sample bottles were capped under water before rinsing them clean. Samples collected were labeled and placed in a cooler box containing ice blocks and then transported within six hours to Eldoret Water and Sanitation (ELDOWAS) laboratories for analysis.

Samples were collected from these streams in the study area since they were found to be the commonly used water sources by locals. The sampling sites were identified to represent even distribution of unprotected streams across the study area.Random sampling was used in the study

3.2.4 Jar tests study

The jar tests was conducted using Junke and Kunkel jar test (Lovibond ET 730) apparatus where the equipment used 4 beakers with 1000 mL capacity each with four paddles rotation. Turbidity, pH and conductivity values were tested before and after the treatment given. The first three beakers were filled with 1000 mL of water in each beaker, while the fourth beaker is left untreated for control. The different coagulant concentrations and amount was then added to the water sample to be tested. After the addition of the coagulant, the water was mixed rapidly using 125 rpm for 5 min and then slowed down to 50 rpm for 30 min. It was then left undisturbed to settle for 1 h. After the settlement of the water treatment, the water was taken and measured.

3.3 Evaluation of the ability of wattle stem charcoal as a filter material in water purification

3.3.1 Designing an Improvised Charcoal Water Filter

Fresh charcoal that had cooled completely was collected. Wattle tree charcoal was used as it was readily available and has no known side effects. The charcoal was

crushed into small bits up to the size of aquarium gravel. The particle sizes of the charcoal were graded from 0.5 mm to 5mm using standard sieves at the Ministry of Public Works laboratory in Eldoret.

The graded charcoal sample was sterilized by boiling in water for 15 minutes and recovered by decanting excess water before use in the filter. A 2-litre cylindrical plastic container with the lower part cut open was obtained. The smaller opening was covered with a piece of fabric that acted to prevent the charcoal from falling out or running through with the water. Approximately 500g of crushed charcoal of varying sizes ranging from 0.5mm, 1.0mm, 2.0mm and 5.0mm was packed into the container tightly. This was meant to create as fine a matrix as possible for the water to drip through slowly, thus trapping more sediment. The crushed charcoal was filled up to about halfway the cylinder. Another piece of cloth was placed on top of the charcoal to prevent it from becoming displaced when water was added. The filter was placed atop a sterile container to collect the filtered water (Appendix 1, Plate 2). Five charcoal filters were designed to be used, each per stream to avoid cross contamination by raw water sample.

3.3.2 Sample Filtration

A 500 ml of raw water samplewas slowly poured into the charcoal filter and allowed to slowly percolate through. The filtrate was collected in a sterilized beaker. The filtered samples were later analysed.

3.4 Determination of the efficiency of *Moringa oleifera* seed extract and wattle stem charcoal filter in water purification

To determine the effectiveness of combined activity of *M. oleifera* and charcoal filter, 500 ml of raw water sample was initially treated with optimum stock solution of *M.*

oleifera. The treated sample was then passed through the charcoal filter in a similar procedure of filtration undertaken above.

3.5 Laboratory analyses

3.5.1 Turbidity

Turbidity measurement was carried out on raw water samples and on samples obtained after the treatments of the various water samples using a HACH DR/2000 spectrophotometer. This is a direct reading multipurpose spectrophotometer. It was configured to read turbidity at the wavelength of 750 nm specified for measuring turbidity. Distilled water was first poured into a 25 ml cuvette and inserted into the spectrophotometer. The calibration button was pressed and the instrument was then calibrated. Each of the samples to be read was poured into a 25 ml cuvette and inserted into the spectrophotometer. The turbidity of the samples was displayed on the LCD panel of the instrument in Nephelometric Turbidity Units (NTU). After each reading, the spectrophotometer was calibrated again with the distilled water before being used on the next sample.

3.5.2 Conductivity

Conductivity is the measure of how well water can pass an electric current. It is an indirect measure of the presence of inorganic dissolved solids such as nitrates, phosphates, sodium, magnesium, calcium, iron and many others. The presence of these substances increases conductivity in water body.

In the current study conductivity of water samples were measured *in situ* using DDS 307A conductivity meter. The conductivity meter was connected with conductivity probe and the probe tip rinsed with distilled water . The conductivity probe was then immersed into sample and the sample stirred evenly with glass bar. The conductivity value was then read.Conductivity was measured in µs/cm.

3.5.3. Potential of Hydrogen (pH)

The pH of the samples were measured using JEENWAY pH meter 3305 in the area of study. The pH electrode were thoroughly rinsed before and between measurements with distilled water to prevent carryover contamination of the tested solutions. The excess rinse water was removed by gently blotting the electrode on laboratory cleaning tissue. The pH electrode was then dipped into the testing solution. The solution was stirred with a magnetic bar (~30 s) with the same stirring rate as for calibration for best results. The pH was completed when the pH reading was stable. The pH values were recorded. The above procedure was repeated for multiple measurements.

3.5.4.Phosphate (PO4)

DREL/2010 spectrophotometer was used for the phosphate analysis. A wavelength of 890nm was set for Phosphorus (PO_4^{3-}). After the correct wavelength was dialed in, the display quickly showed zeroing then mg/L PO_4^{3-} PV. A 10-mL Cell riser was inserted into the cell compartment. A sample of 10 mL was poured into a clean sample cell. One PhosVer 3 Phosphate Powder Pillow was added into the contents of the cell (the prepared sample). The sample was swirled immediately to mix; a blue colour formed showing the presence of phosphate. When the timer beeps, a two-minute reaction period began. Another sample cell was filled with 10 mL of the sample (the blank). After the 2-minutes reaction time, the spectrophotometer displayed mg/L PO_4^{3-} PV. The blank was placed into the cell holder then the light shield was closed. The display showed 0.00 mg/L PO_4^{3-} PV. The stopper was removed. The prepared sample was placed into the cell holder and the light shield

closed tightly. The display indicated the amount of mg/L PO_4^{3-} after pressing the read button.

3.5.5. Nitrate

DREL/2010 spectrophotometer was used for the nitrate analysis. It adopts Cadmium reduction method by using powder pillow. A wavelength of 500 nm was set for high range nitrate nitrogen (NO_3^--N). After the correct wavelength was dialed in, the display quickly showed zeroing then mg/L NO_3^--N HR. 25 mL of the sample was poured into the sample cell. One Nitra Ver 5 Nitrate reagent powder pillow was added into the contents of the cell (the prepared sample). The prepared sample in the cell was vigorously shaken until the timer beeps in one minute. When the timer beeps, a five-minute reaction period began. Another sample cell was filled with 25mL of the sample (the blank). After the 5-minutes reaction, the spectrophotometer displayed mg/L NO_3^-—N HR. The blank was placed into the cell holder then the light shield was closed. The display showed zeroing 0.0 mg/L NO_3^-—N HR. The stopper was removed. The prepared sample was placed into the cell holder and the light shield closed tightly. The display showed the result in mg/L nitrate nitrogen ($NO3^-$—N) after pressing the read button.

3.5.6 Sulphate

DREL/2010 spectrophotometer was used for the sulphate analysis. It is Sulfa Ver 4 method by using powder pillow. A 450 nm wavelength was set for sulphate (SO_4^{2-}). After the correct wavelength was dialed in, the display quickly showed zeroing then mg mg/L SO_4^{2-}. 25 mL of the sample was poured into a clean sample cell. One Sulfa

Ver 4 Sulphate Reagent Powder Pillow was added into the cell containing the sample and swirled to get dissolved in the cell white turbidity developed which shows the presence of sulphate. When the timer beeps, a five-minute reaction period began and the prepared sample in the cell was allowed to stand undisturbed. Another sample cell was filled with 25mL of the (the blank). After the 5-minutes reaction, the spectrophotometer displayed mg/L SO_4^{2-}. The blank was placed into the cell holder then the light shield was closed. The display showed zeroing 0.0 mg/L SO_4^{2-}. The stopper was removed. The sample was placed into the cell holder and the light shield closed tightly. The display showed the result in mg/L sulphate (mg/L SO_4^{2-}) after pressing the read button.

3.5.7 Estimation of Total and fecal coliforms

Analysis of collected raw water samples and treated water samples) to estimate the populations of total coliforms and fecal coliforms was done using the Colilert-18 test procedure. This analysis represented one aspect of water quality whose findings were used to draw inferences about the suitability of the water for use based on average microbial populations as per WHO recommendations.

Colilert®-18 test-kits simultaneously detects total coliforms, faecal coliforms and *Escherichia coli* in water (George *et al.,* 2000). It is based on IDEXX's patented Defined Substrate Technology® (DST®). When total or faecal coliforms metabolize Colilert-18's nutrient indicator, *ortho*-Nitrophenyl-β-galactoside(ONPG), the sample turns yellow. When *E.coli* metabolizes Colilert–18's nutrient indicator, 4-methylumbelliferyl-β-D-glucuronide (MUG), the sample fluoresces (Boubetra*et al*., 2011). Colilert-18 can simultaneously detect faecal coliforms, total coliforms and *E.*

coli within 18 hours to an accuracy of 1cfu/100ml even with as many as 2 million heterotrophic bacteria per 100 ml present (Kramer & Liu 2002).

One pack of Colilert reagent was added to a 100 ml room temperature water sample in a sterile water container. The container was capped and shaken until its contents dissolved. The sample/ reagent mixture was poured into a quanti tray and sealed in a quanti tray sealer. The quanti-tray 2000 of 97 wells was used. The sealed tray was incubated at 37^{o}C for 18 hours. The number of yellow wells which represented total coliforms and yellow/fluorescent wells represented E. *coli* were counted as positive and reference made to the MPN conversion table (Appendix 2) (Chao, 2006).

Fluorescence to detect the presence of *Escherichia coli* was checked using a 6-Watt, 365-nm Ultra violet light lamp within 5 inches of the sample in a dark environment. This procedure ensured that the UV light was directed away from the experimenter's eyes and towards the sample. Colilert results were read after 18 hours, however if the results were ambiguous based on the initial reading, incubating up to additional four hours to allow the color and/or fluorescence to intensify was done. Only sterile, none buffered, oxidant free water for dilutions was used. Aseptic techniques were followed during analysis and good laboratory practice GLP for disposal. Sample tests were stored at 25^{o}C away from light.

3.5.8 Biochemical Oxygen Demand (BOD)

Dissolved Oxygen (DO) was measured using a SX716 Dissolved Oxygen (DO) meter. The machine calibrations were adjusted to read or display 100% active air concentration and the tip of the probe was immersed into the sample in a container and the machine allowed to stabilize before obtaining the actual level of oxygen in parts per million (ppm) which is equivalent to mg/l (APHA, 1998).

Initial DO values were recorded *in situ* and the same samples incubated at 20 ^{0}C for 5 days in dark bottles. This was done in order to avoid some processes like photosynthesis and respiration that could have released or consumed oxygen hence affecting its concentration. Final DO was recorded at the end of 5 days. Biochemical Oxygen Demand after the 5th day was determined in the formula given below:

BOD_5= Final DO-Initial (APHA, 1998). Similar procedure was done for *Moringa oleifera* treated samples and charcoal filtered samples in the laboratory.

3.6 Data analysis

Statistical analysis was done using One-way Analysis of variance (ANOVA) to assess whether significant ($p < 0.05$) variations existed among actual means resulting from the treatments. Separation of means was done by Tukey's test.

CHAPTER FOUR

RESULTS

4.1 Effect of Moringa oleifera and Aluminium sulphate on coagulation of water suspended particles

Jar test results indicated that the optimum dosage rate for efficient removal of turbidity in raw water varied for both *Moringa oleifera* seed extract and Aluminium sulphate.

The most significant finding of using ***Moringa oleifera*** seed extract as coagulant is the reduction from initial reading of turbidity at 40 mg L^{-1} with 85.55% of removal efficiency where the lowest turbidity was achieved compared to aluminum sulphate with 78.72.% turbidity reduction at a concentration of 50 mg L^{-1} as seen in Table 4.1

Table 4.1: Dosage rate and treatment efficiency (%) of *Moringa oleifera* seed extract and Aluminium sulphate coagulants on water turbidity.

Dosage (Mg/l)	Aluminum Sulphate (%)	*Moringa oleifera* (%)
0	0	0
10	24.04	44.09
20	44.09	52.79
30	57.94	66.66
40	70.86	85.55
50	78.72	79.77
60	67.97	78.49

The results obtained for water turbidity upon addition of optimum doses of *Moringa oleifera* and Aluminium sulphate was used as an indicator of the degree of

coagulation. A graphical representation of water treatment with *M. oleifera* seeds extracts and aluminium sulphate is shown in Figure 4.1 below.

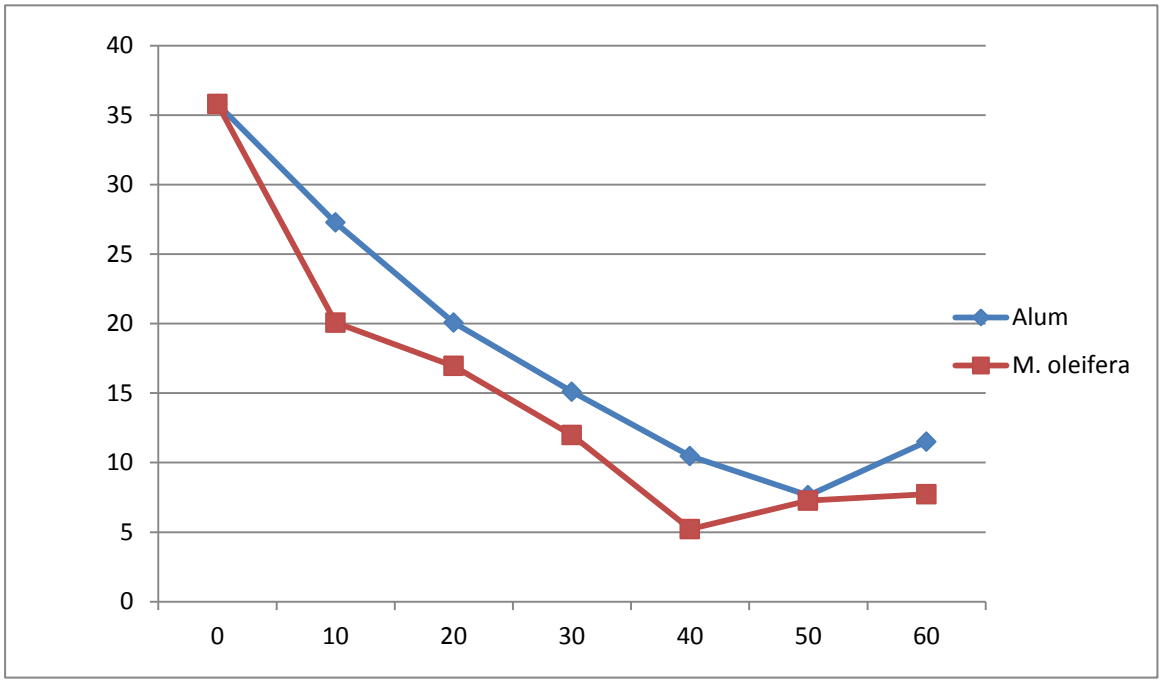

Figure 4.1: Graph showing comparison of dosage (mgL^{-1}) against turbidity (NTU) for *Moringa oleifera* and Aluminium sulphate

Table 4.2: Mean values based on various treatment of raw water samples from different streams.

STREAM	Turbidity	pH	Conductivity	Sulphate	Phosphate	Nitrate	Total coliforms	Fecal coliforms	BOD
Leberio	1069.3	7.40	842.00	195.00	12.25	70.00	2419.0	1978.0	20.0
	936.3	7.20	844.50	29.00	1.90	26.00	1811.0	1671.0	14.3
	52.70	7.70	652.50	24.00	1.00	22.00	1013.0	469.50	13.05
	18.80	7.70	652.50	19.00	0.70	21.00	811.00	37.50	10.55
Malanymaina	900.70	7.60	914.00	107.00	10.30	75.00	2173.5	1449.0	19.00
	498.00	7.00	850.00	22.00	1.62	25.00	1818.0	1195.0	13.80
	38.90	0.80	656.50	18.00	0.80	21.00	950.50	160.00	12.05
	10.80	7.80	662.00	12.00	0.50	19.00	50.00	20.50	9.18
Lemook	104.30	7.20	934.50	125.00	9.30	50.00	530.00	237.00	17.80
	11.90	7.20	858.00	23.00	0.80	27.00	258.50	230.00	13.58
	10.60	7.80	655.50	19.00	0.60	22.00	108.50	81.50	12.70
	5.90	7.70	661.00	14.00	0.30	0.00	4.50	0.00	7.80
Nganiat	225.00	6.90	949.00	949.00	175.00	1.50	1346.5	977.00	12.40
	26.30	7.10	863.50	22.00	0.90	24.00	701.00	499.00	10.80
	12.60	7.50	657.50	17.00	0.40	19.00	330.00	127.50	8.40
	6.60	7.30	654.00	11.00	0.20	18.00	8.00	1.00	6.30
Kapbodigita	797.00	7.20	972.50	180.00	2.40	45.50	1527.5	1267.5	16.40
	365.00	7.10	872.00	24.00	0.90	30.00	1188.5	990.50	15.20
	13.40	7.50	668.00	20.00	0.50	22.00	598.00	127.50	12.30
	6.60	7.50	652.00	16.00	0.20	20.00	14.50	5.50	8.40

Key: (R-Raw water sample; M- Moringa treated sample; C- Charcoal treated sample; MC- Moringa and Charcoal treated sample).

From the table above, the most polluted stream was Leberio. This was noted from its high turbidity levels and a noticeably high microbial load. This could be as a result of its proximity to farmlands. Its accessibility to the surface runoff from farm fields could be a major source of the high level of pollution. The other strems were relatively distant from cultivated farms hence the possible indication of low pollution.

Table 4.3: Mean values based on various treatment of raw water samples for parameters under study.

	Parameters								
Treatment	Turbidity	pH	Conductivity	Sulphate	Phosphate	Nitrate	Total coliforms	Fecal coliforms	BOD
Raw	619.26	7.26	922.4	156.4	7.15	57.1	1599.3	1181.7	17.14
Moringa	369.7	7.12	857.6	60	1.224	26.4	1155.5	9171.0	13.55
Treated Charcoal	25.64	7.66	658.0	19.6	0.66	21.2	600.0	184.4	11.70
Filtered Moringa+Charcoal	9.74	7.64	656.3	14.4	0.38	19.4	177.6	12.9	8.45

Summary of *Moringa oleifera*, charcoal filter and combined treatment of *Moringa oleifera* and charcoal filter on physicochemical parameters.

Table 4.4 Analysis of Variance (ANOVA)

Parameters	**Source of Variation**	Treatment
	F-Value	P-Value
Turbidity	7.111	0.009**
PH	8.931	0.004**
Conductivity	51.384	0.000**
SO_4	6.478	0.012**
PO_4	2.937	0.092
NO_3	2.295	0.143

** Denotes significance at $p<0.05$

Using *Moringa oleifera*, charcoal filter and a combination of *Moringa oleifera* and charcoal filter in water treatment.

Means followed by different letters within a column are significantly different at $p<0.05$.

Table 4.5 Mean (±se) percent reduction of physicochemical parameters

Treatment	*Turbidity*	*pH*	*Conductivity*	*SO_4*	*PO_4*	*NO_3*
B(M oleifera)	*57.65±32.09a*	*1.82±1.92b*	*6.85±4.17a*	*84.05±3.41a*	*72.53±21.18a*	*51.25±13.38a*
C(Charcoal)	*94.66±3.09b*	*5.58±2.72a*	*28.51±3.66b*	*86.97±2.92a*	*86.02±9.18a*	*61.20±8.67a*
D(Combined)	*97.52±1.95b*	*5.30±2.41a*	*28.68±3.99b*	*90.53±2.03b*	*92.91±3.94a*	*64.54±7.61a*

4.2 Effects of Moringa oleifera and charcoal filter on physicochemical parameters of water

Table 4.4 gives a summary of Analysis of Variance for the physicochemical properties of water under study. This values are based on the mean values obtained before and after treatment of the raw water samples obtained from the five strems in Table 4.3 above.

The mean pH of raw water and treated water was found to be within the WHO value of 6.0 to 8.5 of consumable water.

When *Moringa oleifera* was used as coagulant, the conductivity of the stream water reduced by 7% from 922.4-857.6 µs/cm (Table 4.5). Ensuing filtration through the charcoal filter significantly reduced conductivity by 29% from 857.6-658.0 µs/cm (Table 4.5). No significant reductions in conductivity was observed between charcoal and a combination of charcoal and *M. oleifera.*

Levels of sulphate increase with treatment of *Moringa oleifera* seed extract but do not affect the quality of water as it does not increase above the unacceptable levels (Table 2.1).

Moringa oleifera reduced sulphate concentrations by 84%. Filtration over charcoal reduced the sulphate concentration by 87%. A combined activity of *M. oleifera* and the charcoal filter further reduced the levels by approximately 91% (Table 4.4). This reduction was significantly different ($p=0.012$).

The highest phosphate levels was recorded at Nganiat stream with a concentration of 175.00 mg/L, while the lowest concentration was 2.40 mg/L recorded at Kabodigita stream. 80 % of the sampled water had phosphate level beyond the WHO recommended maximum of 5 mg/L. This would pose health effects such as osteoporosis and kidney damage.

Moringa oleifera reduced phosphates by 73%. The charcoal filter reduced the phosphates by 86%. Combination of *M. oleifera* and charcoal filter removed phosphates by approximately 93% (Table 4.4). This reduction was not significantly different (p=0.092)

Moringa oleifera removed nitrates by 51%. The charcoal filter removed nitrates by approximately 61%. Combining *M. oleifera* and charcoal filter reduced nitrates by 65% (Table 4.4). This reduction was not significantly different (p=0.143).

4.3 Effects of Moringa oleifera and charcoal filter on assessment of microbiological parameters

The microbiological parameters under investigation were total coliforms, fecal coliforms and biochemical oxygen demand. Summaries of the findings for these parameters are shown in Tables 4.6 and 4.7.

The interactions between *Moringa oleifera* and charcoal filter had significant ($p \leq 0.05$) effects on total coliforms, fecal coliforms and biochemical oxygen demand (Table 4.6).

on the effect of treatment on percentage reduction of biological parameters (TC, FC and BOD) in sampled water

Table 4.6 Analysis of variance (ANOVA) summary

Source of variation	Total Coliforms		Fecal Coliforms		BOD	
Treatment	F-Value	P-Value	F-Value	P-Value	F-Value	P-Value
	23.38	0.000*	60.996	0.000*	29.402	0.000*

** Denotes significance at p<0.05

Total coliforms in the sample water were as shown in Table 4.6.There were significant differences in total coliforms (p<0.05) among the different treatments of

the sample water in the area of study. *Moringa oleifera* reduced the total coliforms by approximately 33% with p=0.00. Filtration over charcoal reduced the population significantly by 66%. A combination of *M. oleifera* and charcoal filtration reduced the total coliform population by 92%. This reduction was significantly different p=0.00 (Table 4.6).

There was significant reduction in fecal coliforms ($p<0.05$) among the different treatments. *Moringa oleifera* reduced the population by 21%. Charcoal filtration further reduced the population by a significant 82%. A combination of the two treatments reduced the population by approximately 99% (Table 4.6).

The BOD levels were found to be significantly different ($p< 0.05$) among the different treatments (Table 4.6). BOD reduction by *Moringa oleifera* was 20%. Filtration over charcoal reduced the BOD concentration by a further 31.5%. A combination of the two treatments reduced the BOD concentration by 51%.

Microbiological parameters using Moringa oleifera, charcoal filter and Moringa oleifera and charcoal filter combined in water treatment.

Table 4.7 Mean (±) percent reductions

Treatment	Total Coliforms	Fecal Coliforms	BOD
B(*Moleifera*)	32.56±15.88a	21.37±16.94a	19.95±9.36a
C(Charcoal)	66.05±10.68b	82.44±11.19b	31.51±4.76b
D(Combined)	92.36±4.48c	99.23±0.84c	50.66±3.52c

Means followed by different letters within a column are significantly different at $p<0.05$

CHAPTER FIVE

DISCUSSIONS

5.1 The effects of *Moringa oleifera* and Aluminum sulphate on coagulation of water suspended particles.

This study observed that *Moringa oleifera* seed extract and Aluminum sulphate demonstrated the presence of coagulating properties in water treatment. This finding is in line with earlier findings on the use of processed *Moringa oleifera* seed extract as a coagulant in water treatment systems (Jahn, 1988, Ndabigengesere*et al*., 1995, Nkurunzinza, 2009 and Sutherland, 2000). Coagulation of water with *Moringa oleifera* consists of adsorption and charge neutralization while that with alum consists of adsorption and inter-particle bridging resulting in larger flocs which settle faster (Nand *et al.,* 2012). The ability of aluminum sulphate to reduce turbidity of the water sample can be explained as such, when added to water, aluminum salts are hydrolysed producing cationic species responsible for absorbing negatively charged particles of the colloidal and also for neutralizing their charge. Destabilization of the particles then can takes place (Leon *et al*., 2016). A study conducted by Boateng (2001) on the use of Alum and *Moringa oleifera* in surface water treatment recorded 68.8-98.9% reduction in turbidity. Muyibi and Evison (1995) also reported that *Moringa oleifera* could achieve turbidity removal between 92 and 99%. Sani (1990) carried out jar tests with *Moringa oleifera* as the primary coagulant using water from four different sources (viz two surface and two shallow wells) with turbidities from 100 to 800 NTU and 80 to 150 NTU respectively. It was observed that he achieved a turbidity reduction of 92-99%. Coagulation effectiveness of *Moringa oleifera* varies depending on the initial turbidity. However, Muyibi and Okufu (1995) found that *Moringa oleifera* might not be an efficient coagulant for low turbid water. They

documented that the residual turbidity of samples increased with the decrease in initial turbidity at optimum dosage of *Moringa oleifera.* They achieved only 50% turbidity removal from low turbidity surface waters (23–90 NTU).

Previous researchers documented 80–99% turbidity removal by *Moringa oleifera* as primary coagulant both for raw waters and synthetics turbid waters (Muyibi and Okufu, 1995; Ndabigengesere *et al.,* 1995; Muyibi and Evison, 1996) which agrees with this work, where there was 70 - 95% turbidity removal. \

The importance of dosage on turbidity has been emphasized (Zand and Hoveidi, 2015). Coagulant cause an increase in water treatment cost above its ideal dosage and this is not financially reasonable. Another reason why over-dosing should be avoided as well is because there is a probability of restabilization of the destabilized particles to occur due to the saturation of the polymer bridge (Megersa *et al*., 2016). The settling of the particles is disturbed making it impossible to reach the desired turbidity needed. This is the reason why both of the coagulants used showed similar trend of increasing turbidity after achieving their optimum dosage.

In general, the higher the initial turbidity the higher the reduction in turbidity. This is due to increase in suspended particles available or adsorption and colloidal charge neutralization. The net effect is an increase in particle collision frequency and agglomeration rate (LaMer and Healy, 1964, Birkner and Morgan, 1968).

5.2 Efficiency of charcoal filter in reducing pollution levels in stream water

Charcoal filters work by the process of adsorption, whereby pollutant molecules in the water to be treated are trapped inside the pore structure of the carbon substrate. The efficacy of a charcoal filter is also based upon the flow rate regulation. When the water is allowed to flow through the filter at a slower rate, the contaminants are exposed to the filter media for a longer amount of time (Cheremisinoff *et al*.,1980).

Other factors that affect the efficiency of a charcoal filter include the type of compound to be removed. Compounds with high molecular weight and low solubility are better absorbed. The concentration of the compound to be removed is also a factor. The higher the concentration, the higher the carbon consumption. Presence of other organic compounds which will compete for the available adsorption sites also affects the rate of adsorbtion.Besides,the pH of the waste stream is another factor. For example, acidic compounds are better removed at lower pH (Hata *et al.*, 2016).

When *M. oleifera* concentration exceeded the optimum dosage, turbidity is raised up because all colloid shave been neutralized and precipitated with an optimum dosage, so the excess coagulants will cause turbidity in water as they did not interact with oppositely charged colloidal particles (Forkard*et al.*, 1999). The coagulation efficiency of *Moringa oleifera* was found to be dependent on initial turbidity of water samples. Highest turbidity removals were obtained for water with very high initial turbidity. This findings were in agreement with earlier studies done by Katayon*et al.*,(2006).

The only treatment option that gave a significant reduction in turbidity in raw sample was *Moringa* treated sample filtered through charcoal filter with $p \leq 0.005$ at 95% confidence level.The seed kernels of *M. oleifera* according to Schwarz (2000) contain lower molecular weight water-soluble proteins which carry a positive charge. When the seeds are crushed and added to water, the protein produces positive charges acting like magnets and attracting predominately negatively charged particles such as clay, silk, and other toxic particles. Under proper agitation, these bound particles then grow in size to form the flocculates which are left to settle by gravity. This accounted for the effectiveness of *Moringa* as a coagulant for raw water purification.

5.3 Effects of *Moringa oleifera* in enhancing charcoal as a filter material in water purification

Moringa oleifera reduced pH by 2%. The charcoal filter reduced pH by a further 4%. Although charcoal alone reduced pH by a significant 4% more than *M. oleifera*, combining *M. oleifera* and the charcoal filter did not reduce pH significantly more than charcoal alone. It is therefore cheaper to use charcoal alone for this purpose.There were, however, instances where there were significant reductions with the combinations. The variations however fell within the recommended acceptable range of pH for drinking water specified by WHO (2006) of 6.0 and 8.0. The treatments gave a range of 7.1 to 7.75 which falls within the range. When *M.oleifera* seed is used in water treatment it does not modify the water pH (Schwarz, 2000).

However, a higher amount of coagulant, decreases the pH. This can be explained by the fact that the solution becomes more alkaline due to the ability of *M.oleifera* as a coagulant to produce cationic water-soluble protein found in its skin and seeds.These causes acceptance of protons in water by the alkaline amino acids present in *M.oleifera* protein that results in the release of hydroxyl groups which makes the solution become alkaline (Amaglo*het al.*, 2009).

Moringa oleifera reduced conductivity by 7%. This did not affect the quality of water since the conductivity values were within the WHO recommended values of 0-3000 µs/cm. Ensuing filtration through the charcoal filter significantly reduced conductivity further by 22%. No significant reductions in conductivity was observed between charcoal and a combination of charcoal and *M. oleifera.*The addition of coagulant *M.oleifera* may result in the dispersion of some mineral ions and inorganic compounds into afloc which will then be precipitated and separated from the solution.This caused the reduction of electrical conductivity. Reduction of conductivity by charcoal filters is probably due to adsorption by the charcoal.

The highest concentration of phosphates at Nganiat could be attributed to the farming activities being undertaken where there is heavy use of phosphate fertilizers. When the concentration of phosphates rises above 100 mg/L the coagulation processes in drinking water treatment plants may be adversely affected. Manmade sources of phosphate include human sewage, agricultural run-off from crops, sewage from animal feedlots, pulp and paper industry, vegetable and fruit processing, chemical and fertilizer manufacturing, and detergents (John W., 1993). The elevated phosphate concentrations in water have been linked to increasing rates of plant growth, changes in species composition and proliferation of planktonic and epiphytic and epibenthic algae, resulting in shading of higher plants (Mainstone and Parr, 2002).

However, the values of these parameters were reduced as water passed through treatments with *M. oleifera*and filtration over charcoal. The reduction percentages of BOD, SO_4, PO_4 and NO_3 were much lower when water was treated with *M. oleifera* as compared to combined treatment of *Moringa oleifera* and charcoal filtration combined.

The possible reason for reduction of nutrients such as SO_4, PO_4 and NO_3 in the current study may be due to sedimentation as a result of coagulation effect of *Moringa oleifera* and adsorption by charcoal filtration (Weisner*et al*., 1994).

Apart from turbidity removal MO also possesses antimicrobial properties (Olsen, 1987; Madsen *et al.,* 1987 Broin *et al.,* 2002; Ghebremichael *et al.,* 2005). The mechanism by which MO acts upon microorganisms is not yet fully understood.

From the results obtained, Moringa oleifera and charcoal filter reduced total coliform population by 92%.This is not different from a result obtained by research by Madsen *et al.* (1987). They carried out coagulation and bacterial reduction studies on turbid Nile water in the Sudan using *Moringa oleifera* seeds and observed a bacterial

reduction of 90-99.9% within the first one to two hours of treatment. Boateng (2001) also reported the 90-99% reduction in faecal coliform in drinking water.

Broin *et al*., 2002 reported that a recombinant MO protein was able to flocculate gram-positive and gram-negative bacteria cells. On the other hand, MO may also directly act upon microorganisms and result in growth inhibition. For example, Sutherland *et al.*, (1990) reported that MO could inhibit replication of bacteriaphage. Caceres *et al.,* (1991) also observed growth inhibition of *Pseudomonas aeruginosa* and and *Staphylococcus aureus*. Others have also reported antimicrobial effects of recombinant (heterologous) form of MO protein expressed in E. *coli* (Broin *et al.*, 2002; Suarez *et al.,* 2003). Most of the reports on the antimicrobial effect of MO are based on crude extract, and it is difficult to identify the exact nature of the component that carries out the effect. Eilert *et al.,* (1981) attributed the antimicrobial effects to the compound 4 (α - L – Rhamnosyloxy) benzyl isothiocyanate synthesized by the plant.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on this study, the following conclusions were made;

Both coagulants showed comparable turbidity removal performance with *Moringa oleifera* attaining 85.55% and alum 78.72%. The plant species can meet the WHO requirements of drinking water quality in terms of maximum permissible limit of turbidity (≤5 NTU) if they are used for rural area household water treatment with further optimization.

Charcoal filter was found to be highly effective water treatment medium. When tightly packed, the charcoal granules provides very high quality particulate filtration with an immense surface area.It was found to be the best treatment for turbidity. It also improved the taste and odor in water significantly. However, charcoal filters are not the answer to every water-quality problem. Charcoal filters can not purify water by killing any bacteria (or other microorganisms) or by removing bacteria effectively from water. However, homemade charcoal water filters are not only inexpensive, but they can be lifesavers when camping or in emergency situations such as flooding.

There was a remarkable improvement in water quality when *Moringa oleifera* seed extracts were used with charcoal filter. *Moringa oleifera* enhanced the filtration ability of the charcoal filter by initially settling much of the suspended particles in the raw water samples. Subsequent filtration over charcoal filter further eliminated any trace suspensions in water by adsorption. Based on the above outcome, the hypotheses were rejected.

6.2 Recommendations

The *Moringa oleifera* seed extracts can be used in the formulation of a chemical coagulant in water treatmentonly after scientific validation of their safety.

Easy to assemble, inexpensive point of use filters, that incorporate other types of water-treatment strategies, such as reverse osmosis or distillation as prefilters should be designed and produced in mass for local communities. Charcoal filters that incorporate anti-microbial compounds such as silver nitrate can also be designed.

To achieve a high level of water purity, it is important to integrate more than one water treatment process such as coagulation and filtration.

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APPENDICES

Plate 1: *M. oleifera* seeds.

Plate 2:. Sample Charcoal Filter

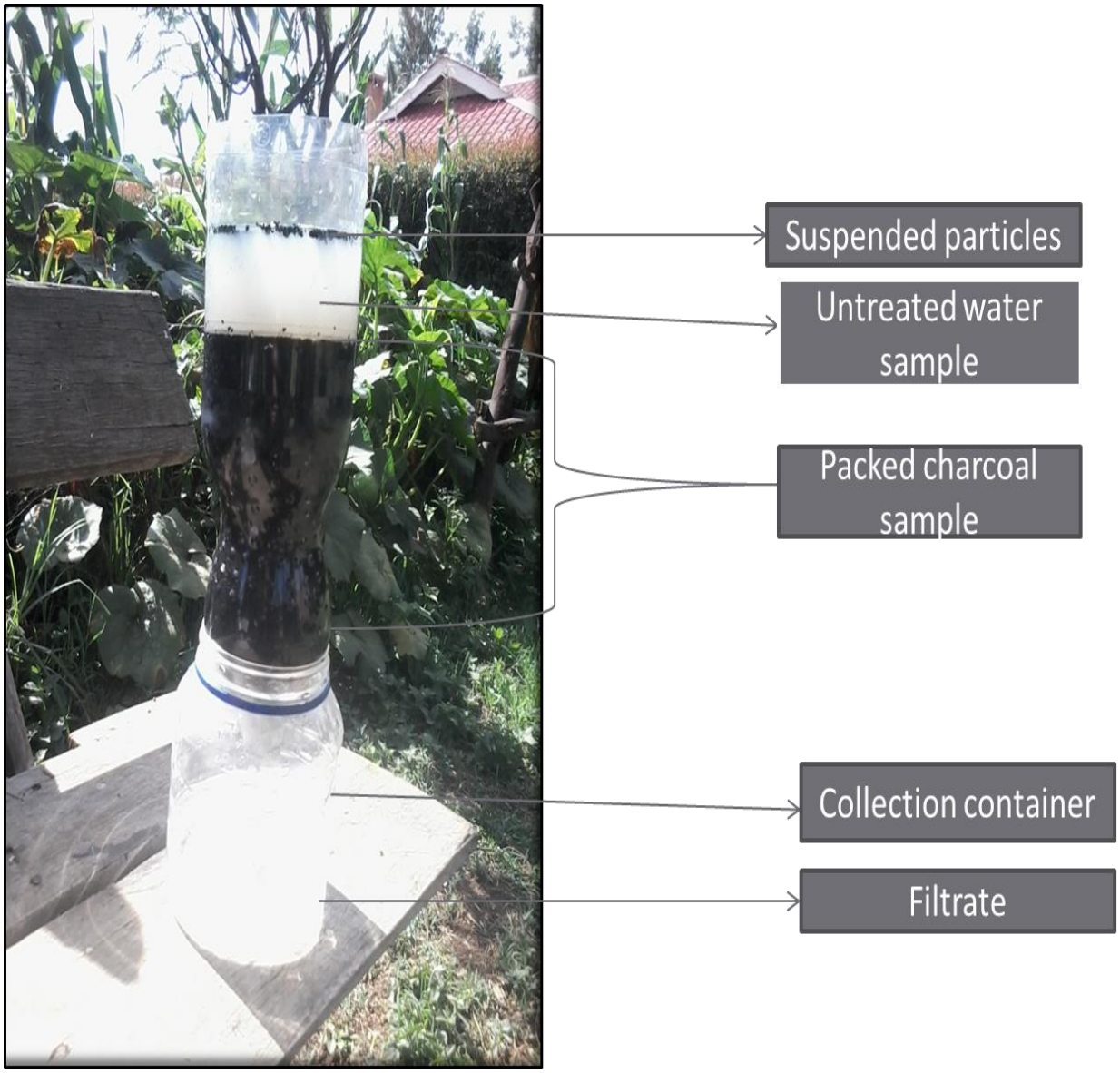
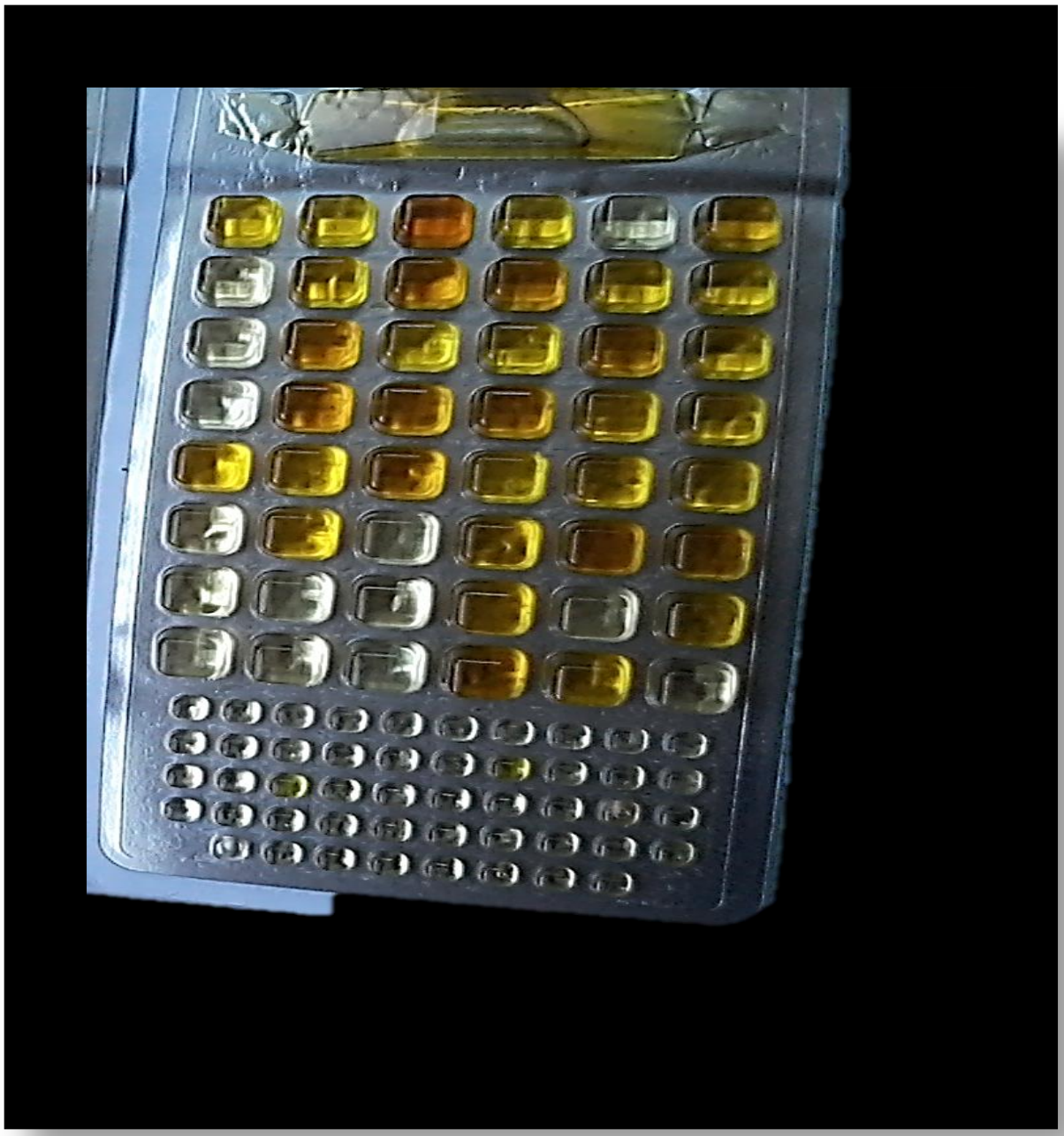


Plate 3: Sample Colilert plate



IDEXX Quanti-Tray*/2000 MPN Table

# Large Wells Positive	# Small Wells Positive																								
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	<1	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.1	15.1	16.1	17.1	18.1	19.1	20.2	21.2	22.2	23.3	24.3
1	1.0	2.0	3.0	4.0	5.0	6.0	7.1	8.1	9.1	10.1	11.1	12.1	13.2	14.2	15.2	16.2	17.3	18.3	19.3	20.4	21.4	22.4	23.5	24.5	25.6
2	2.0	3.0	4.1	5.1	6.1	7.1	8.1	9.2	10.2	11.2	12.2	13.3	14.3	15.4	16.4	17.4	18.5	19.5	20.6	21.6	22.7	23.7	24.8	25.8	26.9
3	3.1	4.1	5.1	6.1	7.2	8.2	9.2	10.3	11.3	12.4	13.4	14.5	15.5	16.5	17.6	18.6	19.7	20.8	21.8	22.9	23.9	25.0	26.1	27.1	28.2
4	4.1	5.2	6.2	7.2	8.3	9.3	10.4	11.4	12.5	13.5	14.6	15.6	16.7	17.8	18.8	19.9	21.0	22.0	23.1	24.2	25.3	26.3	27.4	28.5	29.6
5	5.2	6.3	7.3	8.4	9.4	10.5	11.5	12.6	13.7	14.7	15.8	16.9	17.9	19.0	20.1	21.2	22.2	23.3	24.4	25.5	26.6	27.7	28.8	29.9	31.0
6	6.3	7.4	8.4	9.5	10.6	11.6	12.7	13.8	14.9	16.0	17.0	18.1	19.2	20.3	21.4	22.5	23.6	24.7	25.8	26.9	28.0	29.1	30.2	31.3	32.4
7	7.5	8.5	9.6	10.7	11.8	12.8	13.9	15.0	16.1	17.2	18.3	19.4	20.5	21.6	22.7	23.8	24.9	26.0	27.1	28.3	29.4	30.5	31.6	32.8	33.9
8	8.6	9.7	10.8	11.9	13.0	14.1	15.2	16.3	17.4	18.5	19.6	20.7	21.8	22.9	24.1	25.2	26.3	27.4	28.6	29.7	30.8	32.0	33.1	34.3	35.4
9	9.8	10.9	12.0	13.1	14.2	15.3	16.4	17.6	18.7	19.8	20.9	22.0	23.2	24.3	25.4	26.6	27.7	28.9	30.0	31.2	32.3	33.5	34.6	35.8	37.0
10	11.0	12.1	13.2	14.4	15.5	16.6	17.7	18.9	20.0	21.1	22.3	23.4	24.6	25.7	26.9	28.0	29.2	30.3	31.5	32.7	33.8	35.0	36.2	37.4	38.6
11	12.2	13.4	14.5	15.6	16.8	17.9	19.1	20.2	21.4	22.5	23.7	24.8	26.0	27.2	28.3	29.5	30.7	31.9	33.0	34.2	35.4	36.6	37.8	39.0	40.2
12	13.5	14.6	15.8	16.9	18.1	19.3	20.4	21.6	22.8	23.9	25.1	26.3	27.5	28.6	29.8	31.0	32.2	33.4	34.6	35.8	37.0	38.2	39.5	40.7	41.9
13	14.8	16.0	17.1	18.3	19.5	20.6	21.8	23.0	24.2	25.4	26.6	27.8	29.0	30.2	31.4	32.6	33.8	35.0	36.2	37.5	38.7	39.9	41.2	42.4	43.6
14	16.1	17.3	18.5	19.7	20.9	22.1	23.3	24.5	25.7	26.9	28.1	29.3	30.5	31.7	33.0	34.2	35.4	36.7	37.9	39.1	40.4	41.6	42.9	44.2	45.4
15	17.5	18.7	19.9	21.1	22.3	23.5	24.7	25.9	27.2	28.4	29.6	30.9	32.1	33.3	34.6	35.8	37.1	38.4	39.6	40.9	42.2	43.4	44.7	46.0	47.3
16	18.9	20.1	21.3	22.6	23.8	25.0	26.2	27.5	28.7	30.0	31.2	32.5	33.7	35.0	36.3	37.5	38.8	40.1	41.4	42.7	44.0	45.3	46.6	47.9	49.2
17	20.3	21.6	22.8	24.1	25.3	26.6	27.8	29.1	30.3	31.6	32.9	34.1	35.4	36.7	38.0	39.3	40.6	41.9	43.2	44.5	45.9	47.2	48.5	49.8	51.2
18	21.8	23.1	24.3	25.6	26.9	28.1	29.4	30.7	32.0	33.3	34.6	35.9	37.2	38.5	39.8	41.1	42.4	43.8	45.1	46.5	47.8	49.2	50.5	51.9	53.2
19	23.3	24.6	25.9	27.2	28.5	29.8	31.1	32.4	33.7	35.0	36.3	37.6	39.0	40.3	41.6	43.0	44.3	45.7	47.1	48.4	49.8	51.2	52.6	54.0	55.4
20	24.9	26.2	27.5	28.8	30.1	31.5	32.8	34.1	35.4	36.8	38.1	39.5	40.8	42.2	43.6	44.9	46.3	47.7	49.1	50.5	51.9	53.3	54.7	56.1	57.6
21	26.5	27.9	29.2	30.5	31.8	33.2	34.5	35.9	37.3	38.6	40.0	41.4	42.8	44.1	45.5	46.9	48.4	49.8	51.2	52.6	54.1	55.5	56.9	58.4	59.9
22	28.2	29.5	30.9	32.3	33.6	35.0	36.4	37.7	39.1	40.5	41.9	43.3	44.8	46.2	47.6	49.0	50.5	51.9	53.4	54.8	56.3	57.8	59.3	60.8	62.3
23	29.9	31.3	32.7	34.1	35.5	36.8	38.3	39.7	41.1	42.5	43.9	45.4	46.8	48.3	49.7	51.2	52.7	54.2	55.6	57.1	58.6	60.2	61.7	63.2	64.7
24	31.7	33.1	34.5	35.9	37.3	38.8	40.2	41.7	43.1	44.6	46.0	47.5	49.0	50.5	52.0	53.5	55.0	56.5	58.0	59.5	61.1	62.6	64.2	65.8	67.3
25	33.6	35.0	36.4	37.9	39.3	40.8	42.2	43.7	45.2	46.7	48.2	49.7	51.2	52.7	54.3	55.8	57.3	58.9	60.5	62.0	63.6	65.2	66.8	68.4	70.0
26	35.5	36.9	38.4	39.9	41.4	42.8	44.3	45.9	47.4	48.9	50.4	52.0	53.5	55.1	56.7	58.2	59.8	61.4	63.0	64.7	66.3	67.9	69.6	71.2	72.9
27	37.4	38.9	40.4	42.0	43.5	45.0	46.5	48.1	49.6	51.2	52.8	54.4	56.0	57.6	59.2	60.8	62.4	64.1	65.7	67.4	69.1	70.8	72.5	74.2	75.9
28	39.5	41.0	42.6	44.1	45.7	47.3	48.8	50.4	52.0	53.6	55.2	56.9	58.5	60.2	61.8	63.5	65.2	66.9	68.6	70.3	72.0	73.7	75.5	77.3	79.0
29	41.7	43.2	44.8	46.4	48.0	49.6	51.2	52.8	54.5	56.1	57.8	59.5	61.2	62.9	64.6	66.3	68.0	69.8	71.5	73.3	75.1	76.9	78.7	80.5	82.4
30	43.9	45.5	47.1	48.7	50.4	52.0	53.7	55.4	57.1	58.8	60.5	62.2	64.0	65.7	67.5	69.3	71.0	72.9	74.7	76.5	78.3	80.2	82.1	84.0	85.9
31	46.2	47.9	49.5	51.2	52.9	54.6	56.3	58.1	59.8	61.6	63.3	65.1	66.9	68.7	70.5	72.4	74.2	76.1	78.0	79.9	81.8	83.7	85.7	87.6	89.6
32	48.7	50.4	52.1	53.8	55.6	57.3	59.1	60.9	62.7	64.5	66.3	68.2	70.0	71.9	73.8	75.7	77.6	79.5	81.5	83.5	85.4	87.5	89.5	91.5	93.6
33	51.2	53.0	54.8	56.5	58.3	60.2	62.0	63.8	65.7	67.6	69.5	71.4	73.3	75.2	77.2	79.2	81.2	83.2	85.2	87.3	89.3	91.4	93.6	95.7	97.8
34	53.9	55.7	57.6	59.4	61.3	63.1	65.0	67.0	68.9	70.8	72.8	74.8	76.8	78.8	80.8	82.9	85.0	87.1	89.2	91.4	93.5	95.7	97.9	100.2	102.4
35	56.8	58.6	60.5	62.4	64.4	66.3	68.3	70.3	72.3	74.3	76.3	78.4	80.5	82.6	84.7	86.9	89.1	91.3	93.5	95.7	98.0	100.3	102.6	105.0	107.3
36	59.8	61.7	63.7	65.7	67.7	69.7	71.7	73.8	75.9	78.0	80.1	82.3	84.5	86.7	88.9	91.2	93.5	95.8	98.1	100.5	102.9	105.3	107.7	110.2	112.7
37	62.9	65.0	67.0	69.1	71.2	73.3	75.4	77.6	79.8	82.0	84.2	86.5	88.8	91.1	93.4	95.8	98.2	100.6	103.1	105.6	108.1	110.7	113.3	115.9	118.6
38	66.3	68.4	70.6	72.7	74.9	77.1	79.4	81.6	83.9	86.2	88.6	91.0	93.4	95.8	98.3	100.8	103.4	105.9	108.6	111.2	113.9	116.6	119.4	122.2	125.0
39	70.0	72.2	74.4	76.7	78.9	81.3	83.6	86.0	88.4	90.9	93.4	95.9	98.4	101.0	103.6	106.3	109.0	111.8	114.6	117.4	120.3	123.2	126.1	129.2	132.2
40	73.8	76.2	78.5	80.9	83.3	85.7	88.2	90.8	93.3	95.9	98.5	101.2	103.9	106.7	109.5	112.4	115.3	118.2	121.2	124.3	127.4	130.5	133.7	137.0	140.3
41	78.0	80.5	83.0	85.5	88.0	90.6	93.3	95.9	98.7	101.4	104.3	107.1	110.0	113.0	116.0	119.1	122.2	125.4	128.7	132.0	135.4	138.8	142.3	145.9	149.5
42	82.6	85.2	87.8	90.5	93.2	96.0	98.8	101.7	104.6	107.6	110.6	113.7	116.9	120.1	123.4	126.7	130.1	133.6	137.2	140.8	144.5	148.3	152.2	156.1	160.2
43	87.6	90.4	93.2	96.0	99.0	101.9	105.0	108.1	111.2	114.5	117.8	121.1	124.6	128.1	131.7	135.4	139.1	143.0	147.0	151.0	155.2	159.4	163.8	168.2	172.8
44	93.1	96.1	99.1	102.2	105.4	108.6	111.9	115.3	118.7	122.3	125.9	129.6	133.4	137.4	141.4	145.5	149.7	154.1	158.5	163.1	167.9	172.7	177.7	182.9	188.2
45	99.3	102.5	105.8	109.2	112.6	116.2	119.8	123.6	127.4	131.4	135.4	139.6	143.9	148.3	152.9	157.6	162.4	167.4	172.6	178.0	183.5	189.2	195.1	201.2	207.5
46	106.3	109.8	113.4	117.2	121.0	125.0	129.1	133.3	137.6	142.1	146.7	151.5	156.5	161.6	167.0	172.5	178.2	184.2	190.4	196.8	203.5	210.5	217.8	225.4	233.3
47	114.3	118.3	122.4	126.6	130.9	135.4	140.1	145.0	150.0	155.3	160.7	166.4	172.3	178.5	185.0	191.8	198.9	206.4	214.2	222.4	231.0	240.0	249.5	259.5	270.0
48	123.9	128.4	133.1	137.9	143.0	148.3	153.9	159.7	165.8	172.2	178.9	186.0	193.5	201.4	209.8	218.7	228.2	238.2	248.9	260.3	272.3	285.1	298.7	313.0	328.2
49	135.5	140.8	146.4	152.3	158.5	165.0	172.0	179.3	187.2	195.6	204.6	214.3	224.7	235.9	248.1	261.3	275.5	290.9	307.6	325.5	344.8	365.4	387.3	410.6	435.2

*Quanti-Tray is either a trademark or a registered trademark of IDEXX Laboratories, Inc. in the United States and/or other countries. Covered by U.S. Patent Numbers 4,925,789 ; 5,429,933 ; 5,518,892. Other patents pending.

IDEXX Quanti-Tray®/2000 MPN Table

# Large Wells Positive	# Small Wells Positive																							
	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
0	25.3	26.4	27.4	28.4	29.5	30.5	31.5	32.6	33.6	34.7	35.7	36.8	37.8	38.9	40.0	41.0	42.1	43.1	44.2	45.3	46.3	47.4	48.5	49.5
1	26.6	27.7	28.7	29.8	30.8	31.9	32.9	34.0	35.0	36.1	37.2	38.2	39.3	40.4	41.4	42.5	43.6	44.7	45.7	46.8	47.9	49.0	50.1	51.2
2	27.9	29.0	30.0	31.1	32.2	33.2	34.3	35.4	36.5	37.5	38.6	39.7	40.8	41.9	43.0	44.0	45.1	46.2	47.3	48.4	49.5	50.6	51.7	52.8
3	29.3	30.4	31.4	32.5	33.6	34.7	35.8	36.8	37.9	39.0	40.1	41.2	42.3	43.4	44.5	45.6	46.7	47.8	48.9	50.0	51.2	52.3	53.4	54.5
4	30.7	31.8	32.8	33.9	35.0	36.1	37.2	38.3	39.4	40.5	41.6	42.8	43.9	45.0	46.1	47.2	48.3	49.5	50.6	51.7	52.9	54.0	55.1	56.3
5	32.1	33.2	34.3	35.4	36.5	37.6	38.7	39.9	41.0	42.1	43.2	44.4	45.5	46.6	47.7	48.9	50.0	51.2	52.3	53.5	54.6	55.8	56.9	58.1
6	33.5	34.7	35.8	36.9	38.0	39.2	40.3	41.4	42.6	43.7	44.8	46.0	47.1	48.3	49.4	50.6	51.7	52.9	54.1	55.2	56.4	57.6	58.7	59.9
7	35.0	36.2	37.3	38.4	39.6	40.7	41.9	43.0	44.2	45.3	46.5	47.7	48.8	50.0	51.2	52.3	53.5	54.7	55.9	57.1	58.3	59.4	60.6	61.8
8	36.6	37.7	38.9	40.0	41.2	42.3	43.5	44.7	45.9	47.0	48.2	49.4	50.6	51.8	53.0	54.1	55.3	56.5	57.7	59.0	60.2	61.4	62.6	63.8
9	38.1	39.3	40.5	41.6	42.8	44.0	45.2	46.4	47.6	48.8	50.0	51.2	52.4	53.6	54.8	56.0	57.2	58.4	59.7	60.9	62.1	63.4	64.6	65.8
10	39.7	40.9	42.1	43.3	44.5	45.7	46.9	48.1	49.3	50.6	51.8	53.0	54.2	55.5	56.7	57.9	59.2	60.4	61.7	62.9	64.2	65.4	66.7	67.9
11	41.4	42.6	43.8	45.0	46.3	47.5	48.7	49.9	51.2	52.4	53.7	54.9	56.1	57.4	58.6	59.9	61.2	62.4	63.7	65.0	66.3	67.5	68.8	70.1
12	43.1	44.3	45.6	46.8	48.1	49.3	50.6	51.8	53.1	54.3	55.6	56.8	58.1	59.4	60.7	62.0	63.2	64.5	65.8	67.1	68.4	69.7	71.0	72.4
13	44.9	46.1	47.4	48.6	49.9	51.2	52.5	53.7	55.0	56.3	57.6	58.9	60.2	61.5	62.8	64.1	65.4	66.7	68.0	69.3	70.7	72.0	73.3	74.7
14	46.7	48.0	49.3	50.5	51.8	53.1	54.4	55.7	57.0	58.3	59.6	60.9	62.3	63.6	64.9	66.3	67.6	68.9	70.3	71.6	73.0	74.4	75.7	77.1
15	48.6	49.9	51.2	52.5	53.8	55.1	56.4	57.8	59.1	60.4	61.8	63.1	64.5	65.8	67.2	68.5	69.9	71.3	72.6	74.0	75.4	76.8	78.2	79.6
16	50.5	51.8	53.2	54.5	55.8	57.2	58.5	59.9	61.2	62.6	64.0	65.3	66.7	68.1	69.5	70.9	72.3	73.7	75.1	76.5	77.9	79.3	80.8	82.2
17	52.5	53.9	55.2	56.6	58.0	59.3	60.7	62.1	63.5	64.9	66.3	67.7	69.1	70.5	71.9	73.3	74.8	76.2	77.6	79.1	80.5	82.0	83.5	84.9
18	54.6	56.0	57.4	58.8	60.2	61.6	63.0	64.4	65.8	67.2	68.6	70.1	71.5	73.0	74.4	75.9	77.3	78.8	80.3	81.8	83.3	84.8	86.3	87.8
19	56.8	58.2	59.6	61.0	62.4	63.9	65.3	66.8	68.2	69.7	71.1	72.6	74.1	75.5	77.0	78.5	80.0	81.5	83.1	84.6	86.1	87.6	89.2	90.7
20	59.0	60.4	61.9	63.3	64.8	66.3	67.7	69.2	70.7	72.2	73.7	75.2	76.7	78.2	79.8	81.3	82.8	84.4	85.9	87.5	89.1	90.7	92.2	93.8
21	61.3	62.8	64.3	65.8	67.3	68.8	70.3	71.8	73.3	74.9	76.4	77.9	79.5	81.1	82.6	84.2	85.8	87.4	89.0	90.6	92.2	93.8	95.4	97.1
22	63.8	65.3	66.8	68.3	69.8	71.4	72.9	74.5	76.1	77.6	79.2	80.8	82.4	84.0	85.6	87.2	88.9	90.5	92.1	93.8	95.5	97.1	98.8	100.5
23	66.3	67.8	69.4	71.0	72.5	74.1	75.7	77.3	78.9	80.5	82.2	83.8	85.4	87.1	88.7	90.4	92.1	93.8	95.5	97.2	98.9	100.6	102.4	104.1
24	68.9	70.5	72.1	73.7	75.3	77.0	78.6	80.3	81.9	83.6	85.2	86.9	88.6	90.3	92.0	93.8	95.5	97.2	99.0	100.7	102.5	104.3	106.1	107.9
25	71.7	73.3	75.0	76.6	78.3	80.0	81.7	83.3	85.1	86.8	88.5	90.2	92.0	93.7	95.5	97.3	99.1	100.9	102.7	104.5	106.3	108.2	110.0	111.9
26	74.6	76.3	78.0	79.7	81.4	83.1	84.8	86.6	88.4	90.1	91.9	93.7	95.5	97.3	99.2	101.0	102.9	104.7	106.6	108.5	110.4	112.3	114.2	116.2
27	77.6	79.4	81.1	82.9	84.6	86.4	88.2	90.0	91.9	93.7	95.5	97.4	99.3	101.2	103.1	105.0	106.9	108.8	110.8	112.7	114.7	116.7	118.7	120.7
28	80.8	82.6	84.4	86.3	88.1	89.9	91.8	93.7	95.6	97.5	99.4	101.3	103.3	105.2	107.2	109.2	111.2	113.2	115.2	117.3	119.3	121.4	123.5	125.6
29	84.2	86.1	87.9	89.8	91.7	93.7	95.6	97.5	99.5	101.5	103.5	105.5	107.5	109.5	111.6	113.7	115.7	117.8	120.0	122.1	124.2	126.4	128.6	130.8
30	87.8	89.7	91.7	93.6	95.6	97.6	99.6	101.6	103.7	105.7	107.8	109.9	112.0	114.2	116.3	118.5	120.6	122.8	125.1	127.3	129.5	131.8	134.1	136.4
31	91.6	93.6	95.6	97.7	99.7	101.8	103.9	106.0	108.2	110.3	112.5	114.7	116.9	119.1	121.4	123.6	125.9	128.2	130.5	132.9	135.3	137.7	140.1	142.5
32	95.7	97.8	99.9	102.0	104.2	106.3	108.5	110.7	113.0	115.2	117.5	119.8	122.1	124.5	126.8	129.2	131.6	134.0	136.5	139.0	141.5	144.0	146.6	149.1
33	100.0	102.2	104.4	106.6	108.9	111.2	113.5	115.8	118.2	120.5	122.9	125.4	127.8	130.3	132.8	135.3	137.8	140.4	143.0	145.6	148.3	150.9	153.7	156.4
34	104.7	107.0	109.3	111.7	114.0	116.4	118.9	121.3	123.8	126.3	128.8	131.4	134.0	136.6	139.2	141.9	144.6	147.4	150.1	152.9	155.7	158.6	161.5	164.4
35	109.7	112.2	114.6	117.1	119.6	122.2	124.7	127.3	129.9	132.6	135.3	138.0	140.8	143.6	146.4	149.2	152.1	155.0	158.0	161.0	164.0	167.1	170.2	173.3
36	115.2	117.8	120.4	123.0	125.7	128.4	131.1	133.9	136.7	139.5	142.4	145.3	148.3	151.3	154.3	157.3	160.5	163.6	166.8	170.0	173.3	176.6	179.9	183.3
37	121.3	124.0	126.8	129.6	132.4	135.3	138.2	141.2	144.2	147.3	150.3	153.5	156.7	159.9	163.1	166.5	169.8	173.2	176.7	180.2	183.7	187.3	191.0	194.7
38	127.9	130.8	133.8	136.8	139.9	143.0	146.2	149.4	152.6	155.9	159.2	162.6	166.1	169.6	173.2	176.8	180.4	184.2	188.0	191.8	195.7	199.7	203.7	207.7
39	135.3	138.5	141.7	145.0	148.3	151.7	155.1	158.6	162.1	165.7	169.4	173.1	176.9	180.7	184.7	188.7	192.7	196.8	201.0	205.3	209.6	214.0	218.5	223.0
40	143.7	147.1	150.6	154.2	157.8	161.5	165.3	169.1	173.0	177.0	181.1	185.2	189.4	193.7	198.1	202.5	207.1	211.7	216.4	221.1	226.0	231.0	236.0	241.1
41	153.2	157.0	160.9	164.8	168.9	173.0	177.2	181.5	185.8	190.3	194.8	199.5	204.2	209.1	214.0	219.1	224.2	229.4	234.8	240.2	245.8	251.5	257.2	263.1
42	164.3	168.6	172.9	177.3	181.9	186.5	191.3	196.1	201.1	206.2	211.4	216.7	222.2	227.7	233.4	239.2	245.2	251.3	257.5	263.8	270.3	276.9	283.6	290.5
43	177.5	182.3	187.3	192.4	197.6	202.9	208.4	214.0	219.8	225.8	231.8	238.1	244.5	251.0	257.7	264.6	271.7	278.9	286.3	293.8	301.5	309.4	317.4	325.7
44	193.6	199.3	205.1	211.0	217.2	223.5	230.0	236.7	243.6	250.8	258.1	265.6	273.3	281.2	289.4	297.8	306.3	315.1	324.1	333.3	342.8	352.4	362.3	372.4
45	214.1	220.9	227.9	235.2	242.7	250.4	258.4	266.7	275.3	284.1	293.3	302.6	312.3	322.3	332.5	343.0	353.8	364.9	376.2	387.9	399.8	412.0	424.5	437.4
46	241.5	250.0	258.9	268.2	277.8	287.8	298.1	308.8	319.9	331.4	343.3	355.5	368.1	381.1	394.5	408.3	422.5	437.1	452.0	467.4	483.3	499.6	516.3	533.5
47	280.9	292.4	304.4	316.9	330.0	343.6	357.8	372.5	387.7	403.4	419.8	436.6	454.1	472.1	490.7	509.9	529.8	550.4	571.7	593.8	616.7	640.5	665.3	691.0
48	344.1	360.9	378.4	396.8	416.0	436.0	456.9	478.6	501.2	524.7	549.3	574.8	601.5	629.4	658.6	689.3	721.5	755.6	791.5	829.7	870.4	913.9	960.6	1011.2
49	461.1	488.4	517.2	547.5	579.4	613.1	648.8	686.7	727.0	770.1	816.4	866.4	920.8	980.4	1046.2	1119.9	1203.3	1299.7	1413.6	1553.1	1732.9	1986.3	2419.6	>2419.6