THE EFFECT OF RECYCLING UNTREATED FILTER BACKWASH WATER THROUGH NABAJJUZI RIVER ON THE QUALITY OF FINAL WATER IN MASAKA DISTRICT

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DECLARATION

I Araa J Kennedy herein declare that this work is original and has never been submitted to any University for award of a master's degree. This work is being submitted for the purpose of examination with the approval of my supervisor.

Name: **ARAA JOHN KENNEDY** Sign.................................

APPROVAL

This dissertation has been written under my supervision and has been submitted for the award of the degree of masters of Science in public health of international health Sciences University with my approval as a supervisor.

Sign: ……………………………………
ALIMAH KOMUHANGI

DEDICATION

I dedicate this works to Pichor Knox & siblings and Janet Araa.

ACKNOWLEDGEMENTS

I am greatly indebted to my supervisor **ALIMAH KOMUHANGI** for her tireless guidance and supervision during this study.

My appreciation is also extended to the staff of Masaka Water Treatment plant especially Quality Control section who were very helpful in sample collection and analysis.

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OPERATIONAL DEFINITIONS

Abstraction:	Pumping raw water from the source to the treatment plant.
Filter backwash:	The process of washing the filter sand bed with clean water in a reverse direction.
Spent filter backwash water:	Waste water from washing of dirty filters sometimes referred to as slurry or sludge.
Aesthetic:	Property of water quality visible to the eye like colour turbidity

LIST OF ACRONYMS

FBR:	Filter Backwash Recycling.
Cfu/100ml:	Colony Forming Units per 100 mills.
gpm/sf:	Gallons per minute per square feet.
FBW:	Filtered Backwashed Water.
EPA:	Environmental Protection Agency.
USEPA:	United State Environmental Protection Agency.
FBRR:	Filter Backwash Recycling Rule.
(UNICEF):	United Nation Children Education Fund.
JTU:	Jackson Turbidity Units
Mg/l:	Miligram per Liter.
NSPW:	National Standard for Potable Water.
NTU:	Nephelometric Turbidity Units
NWSC:	National Water & Sewerage Corporation
pH:	Potential of Hydrogen ion
PtCo:	Platinum Cobolt (Unit of measurement for color)
UNBS:	Uganda National Bearue of Standards
UKWIR:	United Kingdom Water Industry Research
WHO:	World Health Organization

ABSTRACT

Background to the study: Water treatment plant in Masaka is currently recycling untreated spent filter backwash water through Nabajjuzi River and yet the plant does not have any treatment facility to treat the filter backwash waste water. Studies in USA indicates that recycling untreated filter backwash waste water will contaminate the corresponding incoming raw water and this overwhelms the water treatment plant's effectiveness and efficiency in removal of pathogens and the final water may no longer be safe for public health consumption.

Objective of the study: To assess the effect of recycling untreated spent filter backwash water through Nabajjuzi River on the quality and safety of final water in Masaka.

Methodology: An experimental study design was used to determine the effect of recycling untreated spent filter backwash water on the quality and safety of final water in Masaka. The effects of recycling untreated spent filter backwash water was assess using univariate and bi-variate analysis. All variables having *p-value* ≤ 0.05 at the bi-variate level using ANOVA were taken as significant predictors.

Results: Returning untreated spent filter backwash water made the raw water at intake point dirtier; colour increased by 68%, turbidity by 55% Iron by 51% and faecal coliform bacteria by 94.6%. Statistical analysis indicated significant difference in raw water quality before and after discharge of untreated spent filter backwash water. No bacterial was detected in all final water samples analyzed however; colour and iron in final water failed a couple of times to meet the National Standard for Potable water.

Conclusion and recommendations: Since colour and iron affects aesthetic property of water and non toxic at concentrations detected in final water, it is safe to conclude that despite recycling of Sent Filter Backwash Water, Masaka final water quality is safe for human consumption.To improve the quality of corresponding raw water and improve treatment efficiency to consistently produced clean and safe water, the filter waste water needs to be treated by constructing a pre-settlement tank or by using a dewatering press before recycling.

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This chapter provides introduction to the study; it describes the background of the study, Statement of the problem, research objectives, research questions, study hypotheses, conceptual framework and justification of the study. This prepared the researcher to assess the effects of recycling untreated Spent Filter Backwash Water (SFBW) on the quality and safety of final water.

Masaka water treatment plant consists of two water works, the ‘old plant Bwala’ and the ‘new plant Boma’ both treatment plants employ conventional water treatment system. Waste water from backwashing of the filters is being recycled into the treatment plant. This waste called Spent Filter Backwash Water (SFBW) is not receiving any form of treatment before return to the treatment plant. According to the United States Environmental Protection Agency (June 2013) spent filter backwash must be adequately treated before recycling or discharge into the environment. It further states that recycling of SFBW without treatment may overwhelm the treatment plant’s effectiveness in pathogens removal and the public may no longer be safe from taking such water. This study was then designed to assess the effect of recycling untreated SFBW on the quality and safety of final water in Masaka.

1.1 Background to the Study

Water is the most abundant of substances on the earth and is almost the only inorganic substance found simultaneously in nature as gas, liquid and solid. Approximately 97.3% of the earth's water is in oceans, 1.74% is locked up in glaciers and only 0.76% is available as fresh water (Igor Shiklomanov et al., 1993). It is unsurprisingly difficult to obtain and keep as a pure substance, it easily gets contaminated (Ray K. Linsleyet et al., 1975).

Untreated SFBW has potential of heavily contaminating the corresponding raw water abstracted for treatment and when, concentrated waste streams of Filtered Backwash Water (FBW) are added to untreated raw water containing an initial concentration of pathogens, the overall concentration of pathogens will gradually increase until final equilibrium is reached. The danger is that a treatment plant's pathogenic removal processes will not be adequate to protect the public, and some dangerous organisms will be released into the treated water (Edzwald, James K et al., 2011). A recent case was the several outbreaks of cryptosporidiosis in Milwaukee USA resulting from ineffective water treatment in 1992, in which an estimated 403,000 people were infected and approximately 69 deaths, of which 93 occurred in persons with AIDS (Water Quality & Health Council 2014 reference).

In a global study conducted by the United Nations, consuming unsafe water is responsible for around 80% of diseases and 30 % of deaths in developing countries throughout the world. Lack of safe water for human consumption is one of the world's leading problems affecting more than 1.1 billion people globally, meaning that one in every six people lacks access to safe potable water (WHO 2010)

The journal "The Facts About The Global Drinking Water Crisis" (2010) stated that in 2006, one third of all nations suffered from clean water scarcity, but Sub-Saharan Africa had the largest number of water-stressed countries of any other place on the planet and of an estimated 800 million people who live in Africa, 300 million live in a water stressed environment and yet water experts like Christopher et al., 2006 indicates that regions that suffer from water stress serve as catalysts for the spread of disease.

Although the provision of safe water services has risen across the globe for example by 2015, 91% of the world's population had access to an improved drinking-water source, compared with 76% in 1990 WHO (June 2015), these gains are being overtaken by population growth. In a rapidly urbanizing world, already some 842 000 people are estimated to die each year from diarrhea as a result of unsafe drinking-water, sanitation and hand hygiene WHO (June 2015). According to the journal Global Water Partnership 2008 (GWP), most of those without improved water supply and decent sanitation live in developing countries.

Uganda had a 75 percent access to safe water sources in urban areas by 2012 this has significantly reduced the burden of water related sicknesses NWSC (2011/12). This was a slightly higher coverage than the regional average for Sub-Saharan Africa (about 60%). This has been possible due to the fact that urban settlements in Uganda have two separate water delivery systems; by NWSC and by the Directorate of Water Development through the local district water supply where NWSC is not operating.

To protect the health of the public from water borne diseases resulting from ineffective water treatment because of recycling untreated SFBW, different states in developed world developed regulations about Filtered Backwash Water Recycling (FBWR). This must be met before a water treatment plant is certified to recycle its spent filter backwash water. According to the United States Environmental Protection Agency (USEPA) spent Filter Backwash Recycling Rule (FBRR) developed in 1996 sets requirements that will allow water treatment plants to recycle its spent filter backwash water. Great Britain also set out their requirement for recycling filter backwash water in United Kingdom Water Industry Research (UKWIR) that came into effect in 1998 (Logsdon, et al., 2000).

Even though Masaka water treatment plant does not meet any of the requirements spelled out in the FBRR or UKWIR, it continues to recycle its untreated filter backwash water that this study investigated the effects on the quality and safety of the final water to public health.

1.2.0 Statement of the Problem

Masaka water treatment plan continues to recycle untreated SFBW which has made the raw water not only difficult to treat but according to Isagara J. et al., (2012),also more expensive to treat this often resulted into poor final water quality.

USEPA (June 2013), states that SFBW shall receive adequate treatment before recycling; Masaka plan does not have a SFBW treatment facility so the waste is recycled untreated.

Currently, SFBW is discharged in Nabajjuzi River so that the river water dilutes the waste before re-abstraction but this is not effective since the discharge point is too close to the intake point and the River is slow flowing.

SFBW contains very high concentrations of pathogens, suspended solids and other organics states Tobiason et al., (1999) and if returned untreated, it may overwhelm the treatment plan's effectiveness in pathogen removal and the final water will no longer be safe for public health use (Edzwald, James et al., 2011). The study thus investigated the effects of recycling untreated SFBW on the quality of the final water for public health consumption.

1.3.0 Objectives of the study

1.3.1 Main Objective

To assess the effect of recycling untreated filter backwash water through Nabajjuzi River on the quality and safety of final water in Masaka District.

1.3.2 Specific Objectives

i. To assess colour and turbidity concentrations in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district.

ii. To assess pH and Iron concentrations in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district.

iii. To assess feacal coliform bacteria concentrations in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district.

iv. To assess the quality of final water treated at Masaka plant abstracted from Nabajjuzi River after untreated SFBW discharge point in terms of colour, turbidity, pH, Iron and feacal coliform bacteria.

1.4 Research Questions

i. What is the colour and turbidity concentration in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district?

ii. What is the pH and Iron concentration in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district?

iii. What is the feacal coliform bacteria concentration in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district?

iv. What is the quality of final water treated at Masaka plant abstracted from Nabajjuzi River after untreated SFBW discharge point in terms of colour, turbidity, pH, Iron and feacal coliform bacteria?

1.5 Study Hypotheses.

i. The colour and turbidity concentration in raw water after the spent filter backwash water discharge point along Nabajjuzi River significantly influences the quality of final water treated at Masaka plant.

ii. The pH and Iron concentration in raw water after the spent filter backwash water discharge point along Nabajjuzi River significantly influences the quality of final water treated at Masaka plant.

iii. The feacal coliform bacteria concentration in raw water after the spent filter backwash water discharge point along Nabajjuzi River significantly influences the quality of final water treated at Masaka plant.

iv. The quality of final water treated at Masaka plant abstracted from Nabajjuzi River after untreated SFBW discharge point meets the national water safety standards.

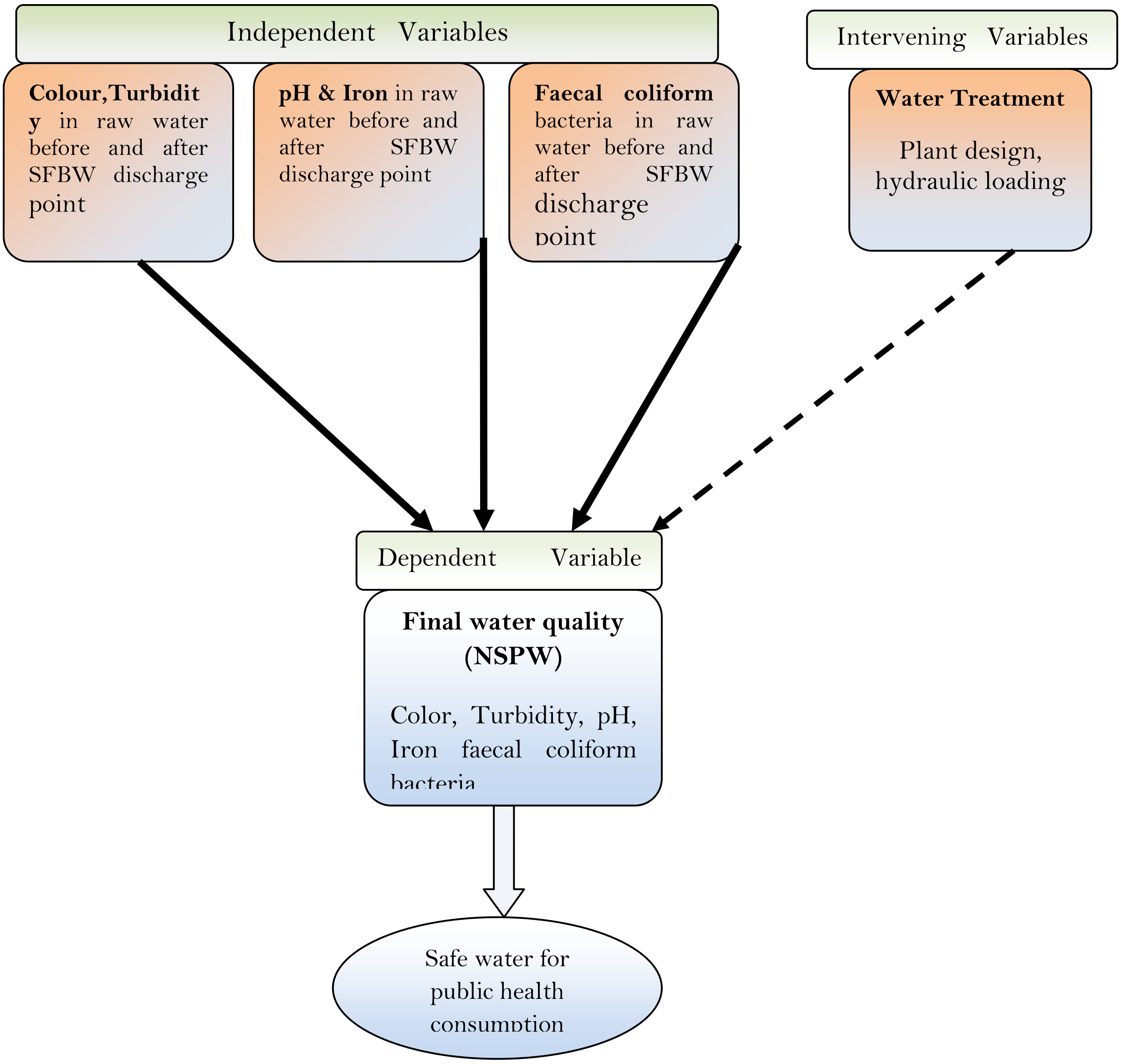
1.6 Significance of the Study.

This study sought to assess the effect of recycling untreated SFBW on the quality and safety of final water in Masaka. Data generated from the study will be used as a basis for subsequent studies and provide interventions on recycling untreated SFBW.

Study findings will also benefit the populace of Masaka municipally in ensuring they get good quality and safe water through intervention by NWSC.

To NWSC, the study findings will provide information that will be useful in developing strategies for better management of SFBW.

1.7 Conceptual Framework



1.7.1 Narrative of conceptual frame work

Spent filtered backwash water (independent variable) from the filters is discharged into a relatively cleaner raw water in river Nabajjuzi hypothesized to affect the raw water quality in terms colour, turbidity, iron and feacal coliform bacteria. The mixed raw water is then re-abstracted and treated in the water treatment plan which is the intervening variable because the treatment plant has factor that can affect the quality of final water like hydraulic loading into the plant but this unit is not under this study. The quality of final water (dependant variable) in terms of colour, turbidity, iron and feacal coliform bacteria will be analyzed to assess if the public receives safe water at the end.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews existing literature on raw water properties, principles of water treatment, origin of filter backwash water, recycling of the backwash water and some principal parameters used to assess quality and safety of final water.

2.1 Raw Water Quality

Naturally, water always contains a measure of dissolved minerals, gasses and suspended particles (Alekseevsky N. I. et al 1995). The range of chemical composition varies diversely and so are the biogenic and organic substances, raw water quality may be affected by natural means depending on the chemistry and biology of the environment through which it flows or physical factors like speed of flow or by anthropogenic activities (Aleksevsky N. I. et al 1995). In a well vegetated wetland there is a lot of carbondioxide generation from the vegetation; this dissolve in the water to form presence of carbonic acids which drops the pH to acidic region of pH (Tsytsarin G.V. et al 1988).

2.2 Parameters to Assess Raw Water Quality

2.2.1 Turbidity

According to Sadar et al., (1996), turbidity is the principal physical characteristic of water and is an expression of the optical property that causes light to be scattered at 90^0 by particles and molecules rather than being transmitted in straight lines through a water sample. Turbidity may also be considered as suspended matter or impurities that interfere with the clarity of the water such as clay, silt, and finely divided inorganic, soluble colored organic compounds, plankton and other microscopic organisms (Kemker, Christine et al., 2013).

However, if turbidity is the optical property of water that scatters light at 90^{o} then; soluble organic matter is not responsible for turbidity because soluble matter absorbs light rather than scatter light therefore soluble matter is responsible for color of water.

Typical sources of turbidity in raw water includes waste discharges, runoff from watersheds, especially those that are disturbed or eroding.

2.2.2 Quantifying Turbidity

The first practical attempts to quantify turbidity dates to 1900 when Whipple and Jackson developed a standard suspension fluid using 1,000 parts per million (ppm) of diatomaceous earth in distilled water (Sadder et al., 1996).

A water sample is poured into a tube until the visual image of the candle flame, as viewed from the top of the tube, is diffused to a uniform glow. When the intensity of the scattered light equals that of the transmitted light, the image disappears; the depth of the sample in the tube is read against the ppm-silica scale, and turbidity was measured in Jackson turbidity units (JTU). Standards were prepared from varied materials found in nature, such as Fuller's earth, kaolin, and bed sediment. These materials however make consistency in uniformity difficult to achieve and was soon abandoned and replaced by standard materials as formazine (Sadar et al., 1996).

2.2.3 Photoelectric Detectors

They became popular since they are sensitive to very small changes in light intensity. These methods provided much better precision under certain conditions.

Finally, turbidity measurement standards changed in the 1970's when the nephelometric turbidity meter, was developed which determines turbidity by the light scattered at an angle of 90^0 from the incident beam (Figure 3 below). Nephelometry has been adopted by standard methods for the examination of water and wastewater as the preferred means for measuring turbidity because of the method's sensitivity, precision, and applicability over a wide range of particle size and concentration AWWARF (1998). The preferred expression of turbidity is Nephelometric Turbidity Units (NTU).

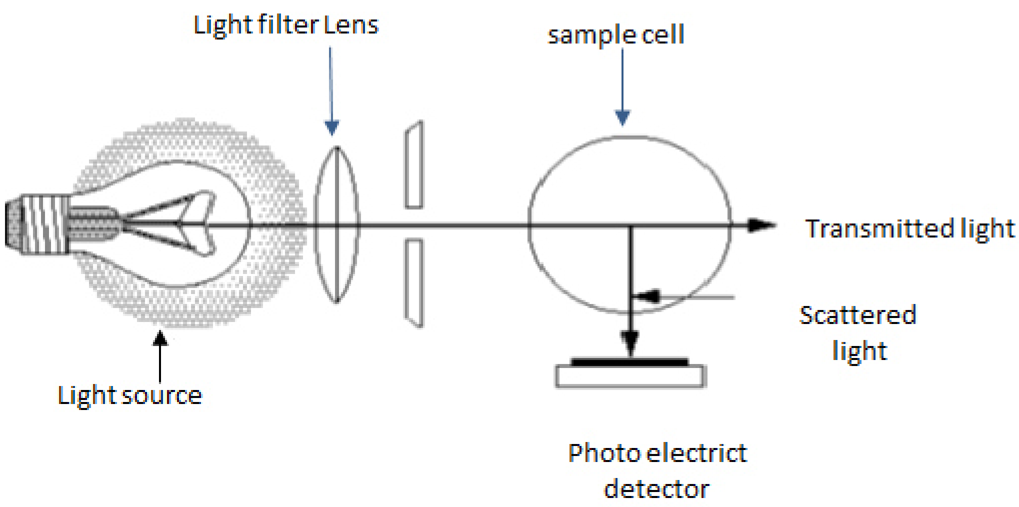


Figure 1: Nephelometric Turbidimeter. Source: Sadar, 1996; photo revised by SAIC, 1998

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2.2.4 Importance of Turbidity in Water Treatment

Particles causing turbidity like clay, silt, and finely divided inorganic matter have a net negative surface charge that aid coagulation and flocculation since most coagulant like Aluminum Sulphate have a net positive charge. Particles causing turbidity also help to add weight to the flocs formed and will settle down faster leaving clean water on the surface (Kemker, Christine et al., 2013).

However, turbidity has been correlated to bacteriological concentration in water; the higher the turbidity, the higher the bacterial load. This is because matters causing turbidity provide both attachment surface for bacterial cells and also could be food material for the bacteria. When turbidity is monitored over a period of time, a spike in turbidity concentration is also a quick indicator that pollution or water quality is being compromised by some activities (Kemker, Christine et al., 2013).

2.3 Total Coliform Bacteria (TC)

These bacteria are found both in the gut of animals and in the environment. They are used in water industry as indicators of water pollution but are generally non pathogenic and if it is the only type of bacteria detected in water, the source of contamination is probably environmental and thus possess little or no threat of pathogens however, if environmental contaminant can leak through, so is pathogenic bacteria; thus it is wise to check for E. coli as well (Edberg et al., 2000)

2.3.1 Escherichia coli

A bacteria usually written in short as E. coli, (coli is Latin for “the colon") is one of the types of bacteria that make up Feacal coliform. Fecal coliform comprise of E; coli, Enterobacter, Klebsieller and Citrobacter bacteria (Edberg et al., 2000). E.coli comprises of many strains of bacteria but only one strain is known to be pathogenic the 0.157 H7. Presence of E-coli bacteria in water is a good indication of a recent fecal contamination. E. coli is an excellent indicator of fecal contamination due to their abundance in the colon of warm blooded animals. It is estimated that a person may excrete up to 10 trillion cells of E. coli a day and if such are analysed, it will certainly show its presence if present in water. (Kemker, Christine et al., 2013).

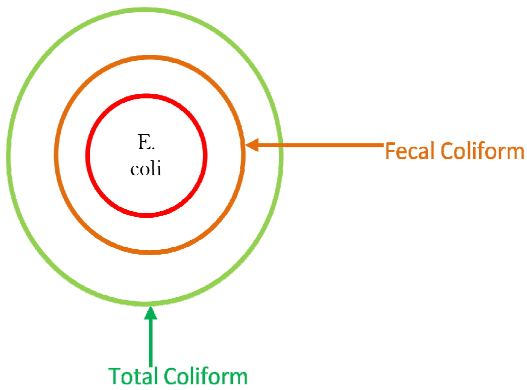

Figure 2: Graphical presentation of Total Coliform, Fecal coliform and E. coli

2.4 Color.

It is considered to be an aesthetic property of water (Kemker, Christine et al., 2013). It is caused by both organic and inorganic substances dissolved and in solution in water. It may also be referred to as the optical property of water that absorbs light thus preventing light to travel through. Colour in water may be measured by means of a spectrophotometer. The principal is that light is passed through a glass cell containing water; some measure of light is absorbed and some transmitted, the amount of light absorbed is proportional to the color of the water and is measures in Platinum Cobolt (standard methods for the examination of water and wastewater 18^{th} edition 1992)

2.4.1 Importance of color in Water Treatment

Most substances dissolved in water giving it color are colloidal organic matter and therefore have a net negative surface charge that aid coagulation and flocculation (Kemker, Christine et al., 2013). However, humic substances causing color with little alkalinity or no surface charge presents a great deal of challenge in water treatment since alkalinity has to be introduced by use fo slake lime before effective coagulation and flocculation.

Color in final water may not necessarily cause any health effects however, final water with color above the NSPW may become visible to the eye and this is offensive making it difficult to drink. (Kemker, Christine et al., 2013).

2.5.0 pH of Water

pH is a determined value based on a defined scale of 0 - 14, similar to temperature. This means that pH of water is not a physical parameter that can be measured as a concentration or a quantity (Kemker, Christine et al., 2013). Instead, it is a figure between 0 and 14 defining how acidic or basic a body of water is along this logarithmic scale. A pH of 7 is considered neutral. The lower the number, the more acidic the water is. The higher the number, the more basic it is. The logarithmic scale means that each number below or above 7.0 is 10 times more acidic than the previous number when counting down or 10 time more basic when counting upwards.

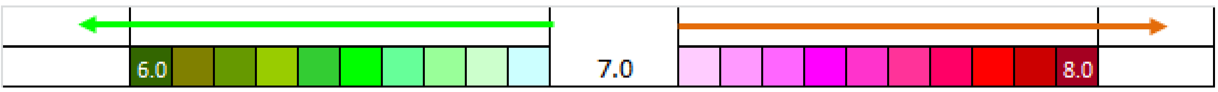

Figure 3: Logarithmic units on a pH scale

pH stands for the "power of hydrogen". The numerical value of pH is determined by the molar concentration of free ignitable hydrogen ions (H+) the effects of hydrogen ions (H^+) and hydroxyl ions (OH^-) determines the pH of a water body. The higher the H^+ concentration, the lower the pH, and the higher the OH^- concentration, the higher the pH. At a neutral pH of 7.0 (pure water), the concentration of both H+ ions and OH- ions are equal or better still paired; thus this equilibrium starts to imbalance as the concentration of one increases, the other will decrease (Kemker, Christine et al.,2013)

2.5.1 Factors that Influence the pH of Water

Factors that can affect pH in water are both natural and anthropogenic. Most natural changes occur due to interactions with surrounding rock (particularly carbonate forms) and other materials. pH can also shifts with precipitation (especially acid rain) and wastewater or mining discharges. In addition, dissolved CO_2 concentrations in water can also influence pH levels (Kemker, Christine et al., 2013)

2.5.2 Importance of pH in Water Treatment.

Many chemical and biochemical reactions take place within certain optimum pH range. The chemistry of coagulation and flocculation is very much pH dependent especially when using Alum as the coagulant. Alum works optimally at a pH range of 5.5-6.5 and any pH outside this range will result into poor coagulation and flocculation with more Alum being used to treat a unit volume of water thus less efficient. (Standard methods for the examination of water and wastewater 18th edition 1992)

2.6.0 Iron

Iron is the second most abundant mineral in the earth crust and accounts for about 5%. (WHO 2003) Water in the soil passing through rocks containing iron mineral will dissolve the iron and gets into solution in water. Under ground where there is very little oxygen, the water remains colorless however, when exposed to air, it quickly gets oxidized to form a brown precipitate Iron will cause reddish-brown staining of laundry, porcelain, dishes, utensils and even glassware (Water Research Watershed Center 2014)

Iron is not hazardous to health unless it goes beyond 40mg/l of your body weight; it is taken as a secondary aesthetic contaminant. Iron helps transport oxygen in the blood (WHO 2003).

2.7.0 Origin of Sent Filter Backwash Water from Water Treatment:

2.7.1 Introduction.

One of the prime objectives of water treatment is the removal of Colloidal impurities of which organic matter is of foremost importance, it should be emphasized that impurities of an organic nature are far more objectionable from a hygienic point of view than impurities of a mineral nature therefore water treatment technology design should always be aimed at achieving the maximum possible removal of organic matter (LeChevallier et al., 2004)..

According to Hunter Water journal (2015), water treatment in principle can be divided into three main stages:

2.7.2 Primary Treatment:

Includes raw water abstraction, screening to remove large floating matter in suspension and sometime includes chemical pre oxidation with chlorine depending on the quality of raw water.

2.7.3 Secondary Treatment

This involves application of chemical coagulants to aid in the removal of the colloidal impurities of which organics are the most important then followed by settlement in clarifier tanks and supernatant taken for filtration.

The amount of chemicals coagulant to be added in water is first done in the laboratory a test called jar test, when the optimum dose is found, that dose is then transferred and applied in the treatment plant.

2.7.4 Tertiary Treatment

This is majorly the addition of chemical disinfectant like chlorine to kill bacteria making the water bacteriologicaly safe for public consumption. The amount of chemical disinfectant added in the water is first determined in the laboratory a test called chlorine demand test. The optimum dose found in the laboratory is applied in the plant (Lechevallie .m.,& keung au .K., et al., (2004).

2.8.0 Water filtration using Rapid Sand Filtration

Rapid sand filtration (RSF) in water industry had its origin in the USA toward the end of the 19^{th} century and soon gained popularity by the 1920s. RSF is purely a physical process where water is passed through a filter bed consisting of various layers of different sand particles from about 0.8 – 1.2 mm on top layer to gravel size at the bottom. Bacteria and organics are safely held within the first layer of sand media (Dijk & Oomen et al., 1978)

Rapid Sand Filtration has demonstrated high effectiveness in turbidity removal if properly applied (Brikkr, Bredero at el., 2003) Turbidity of filtered water less than 0.1 NTU are achievable. Whereas RSF are effective in reducing turbidity if combined with pre-treatment, it is not effective in removal of all bacteria and viruses, (WHO 1996).

According to Schmitt and Shinault et al., (1996), the filtering process in RSF are governed by two principles; relatively large particles get stacked between the sand grains on the top layer of the filtering bed while smaller particles adhere to the sand surface caused by Van der Waals forces.

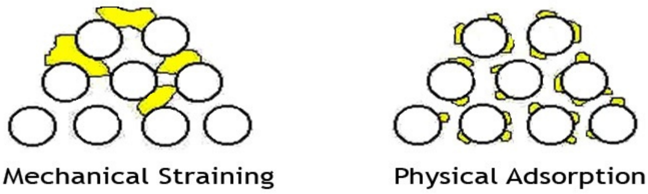

Figure 4: Schematic of basic filtration principles. Source: Schmitt & Shinault (1996)

2.8.1 Filter Backwashing

2.8.2 Definition.

Passing clean treated water through the filter bed in a reverse direction typically lasting anywhere between 10 – 25 minutes and at a maximum rate of 15 to 20 gpm/ft depending on plant design and raw water quality, (Cornwell at el., 2001).

Continual water filtration and retention of particles within the filter bed through sieving and adsorption will eventually clog the filters and reduce filtration efficiency (Marco, Bruni Spuhler at el., 2012). To reinstate the performance of the filters once again, the filters need to be cleaned and this is done through a process called filter backwashing. The resultant water flashed from the filter bed carries high concentration of mainly suspended particles, residual coagulants, organics and bacteria, (Cornwell at el., 2001). Due to the content of the untreated spent filter backwash water, it is required that water treatment companies treat the waste prior to discharge to the environment or recycling (UNEP 1998).

2.8.3 Water Quality of Filter Backwash Water

The main reason for treating SFBW is to reduce the concentration of pathogenic microbes in public drinking water systems by helping to ensure that recycle practices do not compromise the ability of treatment plants to produce safe drinking water (FBRR Technical Guidance Manual 2012).

The quality of spent filter backwash water however is dependent to a great extern on the treatment plan design (Cornwell et al., 2001). In his study, Cornwell et al., (2001) stated that the quality of spent filter backwash water was compared to raw water quality in 146 samples and the result found out that bacteria such as Giardia and Cryptosporidium in spent filter backwash water were observed to vary anywhere between 16 to 21 times higher than the corresponding raw water samples. The same study, Cornwell et al., (2001) found out that turbidity in spent filter backwash water ranged anywhere between 150 – 250 NTU but peaks of up to 400 NTU was reported by Edzwald, Tobiason et al., (1999).

Other contaminants contained in the spent filter backwash water can impact on the entire treatment plant performance and ultimately on the quality of the final water produced (USEPA 2013). Edzwald, James et al., (2011) found Manganese, TOC, Aluminum, and Iron concentrations to be higher in spent filter backwash water as compared to the corresponding raw water.

2.8.4 Filter Backwash Recycling

When wastes water resulting from the backwashing of the filters are returned to join the raw water then into the treatment plant; this constitutes filter backwash recycling. If concentrated spent streams of sludge from the filters are added to untreated water containing an initial concentration of pathogens, the overall concentration of pathogens in the combined raw water will gradually increase until final equilibrium is reached between SFBW and the raw water combined with SFBW. The danger is that a plant's pathogenic removal processes will not be adequate to protect the public, and some dangerous organisms will be released into the treated water (Edzwald, James et al., 2011).

2.8.5 Treatment of Spent Filter Backwash Water.

SFBW may be discharged without treatment if it is joining a sanitary sewer system or it must adequately be treated if it is to be recycled within the plant (Baruth, Edward et al., 1990).

Failure to treat the SFBW and reintroduction of the resulting poor quality water into the main water treatment plant can cause overall process distress that will result in the production of poor quality treated drinking water (Edzwald, James et al., 2011).

There are various treatment technologies currently being applied to treat SFBW prior to return to the water treatment units; these range from full chemical (coagulation using polymer) and physical treatment filtration or gravity settlement before recycling.

In either case, an equalization basin is the first unit constructed to receive SFBW and kept at a constant mix to avoid settlement of solids and sludge which will help to reduce the hydraulic impact of recycle return to the next treatment unit. This improves performance of any SFBW treatment systems utilized prior to recycle return point (Water Research Foundation 2010) figure 2 is a schematic of the origin of SFBW treatment and return.

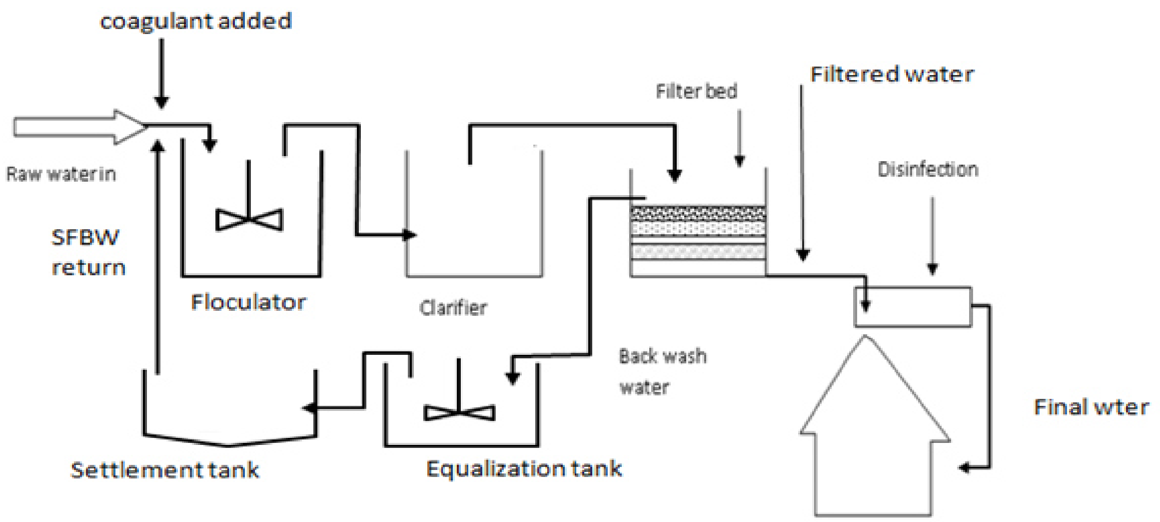

Figure 5: Schematics showing origin of SFBW and treatment units before return to the plant.

Without equalization basins, each succeeding episodes of backwash could create sporadic spikes of contaminants like solids and bacteria concentration into the next treatment unit thereby choking the treatment plants efficiency in pathogen removal (Edzwald, James et al., 2011).

According to various studies carried out by Water Research Foundation (2010), it recommends addition of chemical coagulants (like polymers) for effective treatment of SFBW prior to recycle return or disposal. However, depending on the quantity and contents of the SFBW, construction of a second basin; a quiescent gravity settling can be done to settle solids there by reducing contaminants, including particulate matter to levels equal to or below levels in the corresponding raw water at point of recycle return. In this way the recycle cannot increase contaminants entering the plant above that initially present in the raw water and will not compromise the ability of treatment plants to produce safe drinking water for public health (FBRR Technical Guidance Manual 2012).

The journal USEPA (2010) states that SFBW recyclers must maintain residual disinfectant like chlorine in the distribution above 0.2mg/l and total chlorine of 1mg/l for more than four consecutive hours. It further states that the concentration of the residual disinfectant shall be maintained above 0.2mg/l in not less than 95% of the samples collected in any two consecutive months the public water system supplies water to the people. This standard requirement presents a great challenge to developing countries where maintenance of residual disinfectant above 0.2mg/l is seldom met; this is due to a number of factors ranging from old installations, vandalism, busts and breaking of pipes during road construction.

Turbidity is also one of the parameters looked at when considering SFBR. This is because turbidity provides habitat for microbes and sometimes the organics in suspension act as food material or provided protection to the bacterial from chemical oxidation. The USEPA (2010) requires that for SFBW to be recommended, turbidity levels in final water shall consistently in representative samples be equal or less that 0.3 NTU or will not exceed 1 NTU at all times in at least 95% of all samples analyzed in a month.

CHAPTER THREE

METHODOLOGY

3.0 Introduction.

This chapter discusses the methodology used in data collection. This includes the study design, Source of data, Study population, sample size determination, sampling procedure: study variable, Data collection techniques, data collection tool, data generation, quality control and the study limitation.

3.1 Study Design.

An experimental study design was used to determine the effect of recycling untreated spent filter backwash water on the quality and safety of treated final water for public health consumption in Masaka. This was because experimental study design aims at examining the effect of independent variable on the dependent variable where the independent variable are manipulated and its effect are studied on the dependent variable.

3.2 Source of Data.

3.2.1 Primary Data

A quantitative laboratory and field analysis of water samples collected from the different sampling points generated the primary data that was used to assess the effects of recycling untreated SFBW on quality and safety of final water.

3.2.2 Secondary Data

This was from reviewed lit used to support the discussion of the study finding.

3.3 Study Population.

The study population was represented by the raw water under study before and after the discharge point of the untreated spent filter backwash water along Nabajjuzi River and final water. Each time a sample was taken, 1000ml was the study unit and used as a representative sample of raw water from each point and 1000ml for final water was used as the study unit.

3.4 Sample Size.

This was calculated based on Raosoft sample size determination formula below:

$$x = Z(^{c}/_{100})^2 r(100-r)$$

$$n = {}^{N x}/_{((N-1)E^2 + x)}$$

$$E = \text{Sqrt}[{}^{(N - n)x}/_{n(N-1)}]$$

where *N* is the population size, *r* is the fraction of responses that you are interested in, and *Z*(*c*/100) is the critical value for the confidence level *c*. Substituting, we get margin of error at 5%, with confidence limit of 95% population size was substituted for number of days available for sampling in the month of October 2015 this was 15 days and a distribution of 50%. From this, the minimum recommended sample size was therefore15 samples of water over a period of 1 month.

There were five sampling campaigns during the month of October 2015. On each sampling campaign, a sample was collected from each of the three sampling sites totaling to three samples. At the end of the sampling campaign, a total of 15 samples were collected.

3.5 Sampling Procedure:

Samples for physic – chemical testes where collected into clean 1000 ml plastic bottles while samples for bacterological testes were collected into sterile 200ml glass bottles. A dip water sampler was used to collect water samples from point 1 and point 2 while samples from point 3 were collected from a final water tap on the raising main.

3.5.1 Sampling from point upstream and intake along the river.

- Labeled each sampling bottle with date, sample name and time.
- The water sampler was dip into raw water to the depth of 0.5 meters. And a sample was grabbed and brought to the surface.
- The tap on the dip sampler was then opened and aseptically, the bacteriological bottle was filled first and the physic – chemical bottle was also then filled.
- The samples were put in a cool box with icepacks to keep temperature below 8 ^{o}C
- pH measurement was done on the sample that remained in the dip sampler and results recorded in a field note book

3.7 Independent Variable

Colour and turbidity content of raw water before and after the untreated spent filter backwash water discharge point.

pH and Iron content of raw water before and after the untreated spent filter backwash water discharge point.

Feacal coliform bacteria content of raw water before and after the untreated spent filter backwash water discharge point.

3.6 Dependent variable

Quality of final water measured against safety standard stated in the National Standard for Potable Standard in table 1 below.

Table 1 National Standard for Potable Water

National Standard for Potable Water		
Parameter	**Units of measurement**	**Safety standard range**
Colour	Platinum Cobalt (PtCo)	0.0 - 15
Turbidity	Nephelometric Turbidity Units (NTU)	0.0 – 5.0
pH	Units	6 .0 - 8.5
Iron total	Milligrams per litre (mg/l)	0.0 - 0.3
Feacal coliform	Colony Forming Units per 100 mills (CFU/100ml)	0

3.8 Data Collection Techniques

Techniques for data collection were all based on approved methods for analysis of water and waste water published in the Standard methods for the examination of water and wastewater 18th edition for both microbiological and physic – chemical techniques.

3.8.1 Data Collection Tools

Tools that were used in data collection were water laboratory and field analytical instruments such as:

- pH meter was used in collecting field data on pH values on both raw water and final water.
- Turbidity meter 2100N was used to collect data on turbidity values on both raw water and final water.
- HACH DR 6000 spectrophotometer was used to collect data on colour and Iron total values on both raw water and final water.
- Data on optimum chemical dose determination was collected by use of Stuart Floc Tester on raw water.

- Data on Feacal coliform bacteria was collected by use of quatitray sealer and an incubator on both raw water and final water.
- Free residual chlorine data was collected by use of a Hach chlorine colorimeter on final water samples.

3.8.2 Plan for Data Analysis

Data collected through laboratory and field analysis of the water samples were reviewed and entered into excel spread sheet. Analysis of data was done at two levels, univariate, and bivariate; at univariate analysis, raw water samples were analyzed and presented in percentages and graphs. ANOVA was done at bivariate level to test difference on water samples collected from upstream and downstream. All variables having p value $\leq \alpha$ of 0.05 and *F statistics* > *F critical* in the bivariate analysis were taken as significant predictors.

3.9 Quality Control

3.9.1 Validity

To ensure validity of data collected, all analytical equipment were calibrated before analysis of each set of samples, while microbiological analysis of faecal coliform was carried out alongside controlled organisms as positive control while sterile distilled water was used for negative controls.

3.9.2 Reliability

All tests were done in duplicates and average of the two values were presented as results from each test done on each sample this ensured reproducibility of data collected.

Besides, all analytical methods were based on Standard methods for the examination of water and wastewater 18th edition

3.9.3 Training Research Assistants

Research assistants used were already seasoned long term technicians of NWSC each having experience in water sampling and analysis for over five years. They were however guided on where the samples were to be collected from, dates of sample collection and analysis.

3.10 Ethical consideration

This research was granted by the university to be carried out. National Water and Sewerage Corporation the department of research and development were contacted with the proposal who also granted permission for this study to be carried out in Masaka.

3.10.1 Respect for autonomy

The researcher sought consent from Masaka Area Manager collect water samples for this study in his jurisdiction.

3.10.2 Justice

The study was carried at Masaka which has problems with final water quality regarding colour and iron

3.10.3 Non Malficience

No one around Nabajjunzi and Masaka water treatment plant was harmed during the study period.

3.11 Limitations of the study

A further study regarding the effect of recycling untreated SFBW on performance of each water treatment unit within the treatment plant and the cost implication need to be done.

This study considered faecal coliform bacteria that can be killed or oxidized by chlorine disinfection so that even if they go through sand filters, they still will be killed at disinfection however, there are bacteria that are not killed by chemical disinfection and once they have gone through the filters, they will cause infection such bacteria need to be studied with the recycling of untreated SFBW.

CHAPTER FOUR

PRESENTATION OF RESULTS.

4.0 Introduction

This chapter presents the results from the study starting with the descriptive analysis followed by a bivariate analysis by use of ANOVA. Raw water test results on samples taken before the spent filter backwash discharge point, (upstream) and raw water tests results on samples taken after the spent filter backwash discharge point (Intake). Final water quality results in comparison to safety standard as indicated in the Uganda National Standard for Potable Water is presented last.

4.1 Descriptive Analysis

4.1.1 Description of Water Sampling Points

A total of 15 water samples were collected and analyzed from 3 different sampling points; 5 samples were taken from each sampling point as indicated in table 1 below.

Table 2: A description of water sampling points.

No.	Water sampling point	Number of water samples
1	Before the spent filter waste discharge point - Upstream	5
2	After the spent waste discharge point - intake	5
3	Final treated water from the water treatment plant	5
Total number of samples		15

1.2 Colour and turbidity concentrations in raw water form upstream and intake points along Nabajjuzi River in Masaka district.

Raw water samples collected from upstream and intake points were analyzed and results indicates that average colour and turbidity were more concentrated (69% and 56%) in intake samples after the untreated SFBW discharge point than in upstream samples before the untreated SFBW discharge point. There was also a wide variation in both colour and turbidity concentration downstream at the intake point as indicated by the standard deviation. Colour and turbidity concentrations in raw water samples taken along Nabajjuzi River are presented in table 3 below.

Table 3: Colour and Turbidity in raw water before and after SFBW discharge

Raw water				
	Colour concentration in Platinum Cobalt units		Turbidity concentration in Nephelometric Turbidity Units	
Dates	Upstream	Intake	Upstream	Intake
12.10.15	164	547	8.36	21.4
16.10.15	156	680	7.88	16.8
21.10.15	162	547	8.36	21.4
27.10.15	132	523	7.94	20.5
31.10.15	178	214	8.26	11.8
Avg	158.4	502.2	8.16	18.38
STDV	16.8	172.6	0.2	4.1
%	68.5% more colour at intake		55.6% more turbidity at intake	

A graphical presentation in figure 6 indicates concentration trends of both colour and turbidity remained low and with less fluctuation in upstream samples but varied a lot in intake samples during the study period, concentration of both colour and turbidity were high in intake samples.

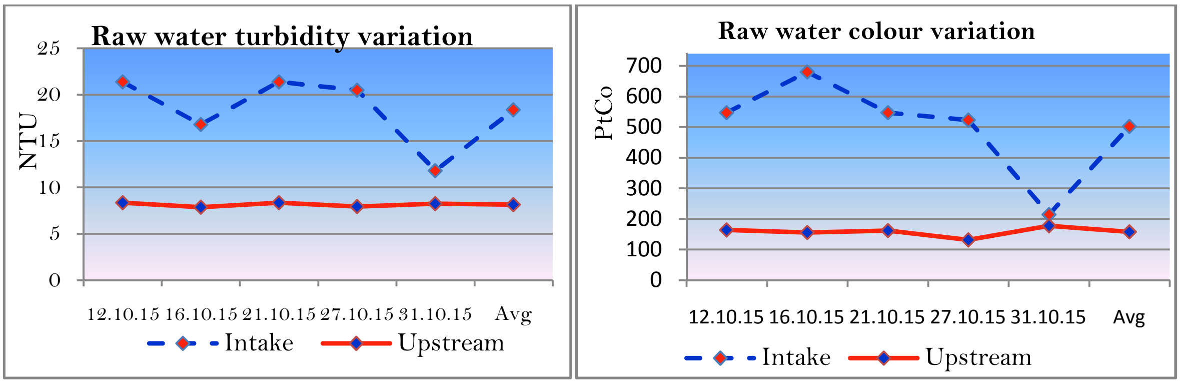

Figure 6: Colour and turbidity trends in raw water at upstream & intake

4.3 pH and Iron concentrations in raw water from upstream and intake points along Nabajjuzi River in Masaka district.

Average pH values upstream and intake did not show much difference 5.4 and 6.0 respectively. Average Iron concentration was 49.1% higher after the discharge in intake samples than in upstream samples. Iron concentration fluctuation was higher in intake samples as compared to upstream samples. The results of pH and colour concentrations are presented in table 4

Table 4: pH and Iron in raw water before and after untreated SFBW discharge

Raw water quality				
	pH units		Iron concentration in mg/l	
Dates	Upstream	Intake	Upstream	Intake
12.10.15	5.1	6.2	10.10	16.5
16.10.15	5.6	5.0	8.38	26.78
21.10.15	5.1	6.2	10.2	16.5
27.10.15	5.0	6.9	8.47	14.22
31.10.15	6.1	5.9	8.28	15.30
Avg	5.4	6.0	9.09	17.86
STDV	0.5	0.7	1	5.1
%	10.0 % more units upstream		49.1% more iron in intake	

A graphical presentation indicates a stable pH value in both points with a very narrow difference of 0.6 pH units. Iron concentration in upstream samples had very little variation and remained less concentrated in comparison to intake samples; there was also a wider variation in Iron concentration in intake samples. pH and Iron concentration trends during the study period are presented in figure.

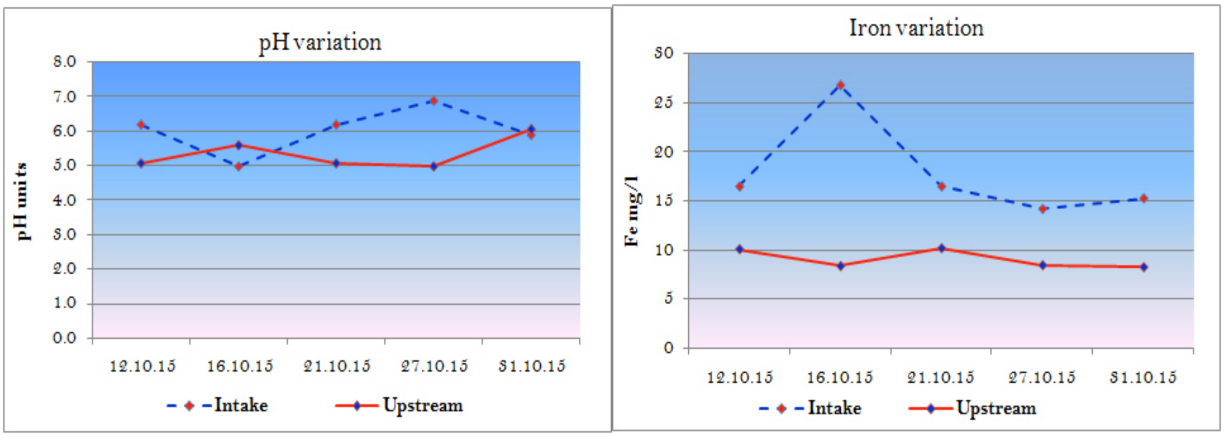

Figure 7. pH and iron variation in raw water at sampling point 1 upstream & 2 intake

1.3 Feacal coliform bacteria concentrations in raw water from upstream and intake points along Nabajjuzi River in Masaka district

Average feacal coliform bacteria concentration remained low in upstream samples by 94.6% as compared to feacal coliform concentration at intake. Standard deviation indicates that feacal coliform concentration fluctuated more at intake unlike in upstream samples. Table 5 presents results of feacal coliform concentration before and after the spent filter backwash point.

Table 5: Feacal coliform results in raw water before and after SFBW discharge

Raw water feacal coliform - colony forming units/100ml		
Dates	Upstream	Intake
12.10.15	34	247
16.10.15	21	476
21.10.15	27	393
27.10.15	17	162
31.10.15	22	973
Avg	24.2	450.2
STDV	6.5	316.9
%	94.6% more faecal coliform in intake	

A graphical presentation shows feacal coliform concentration in all samples analyzed from intake samples to be above the concentration in upstream samples further, there was high fluctuation in feacal coliform concentration in intake samples unlike in upstream samples. Trends in feacal coliform concentration at both points are shown in figure 8 below.

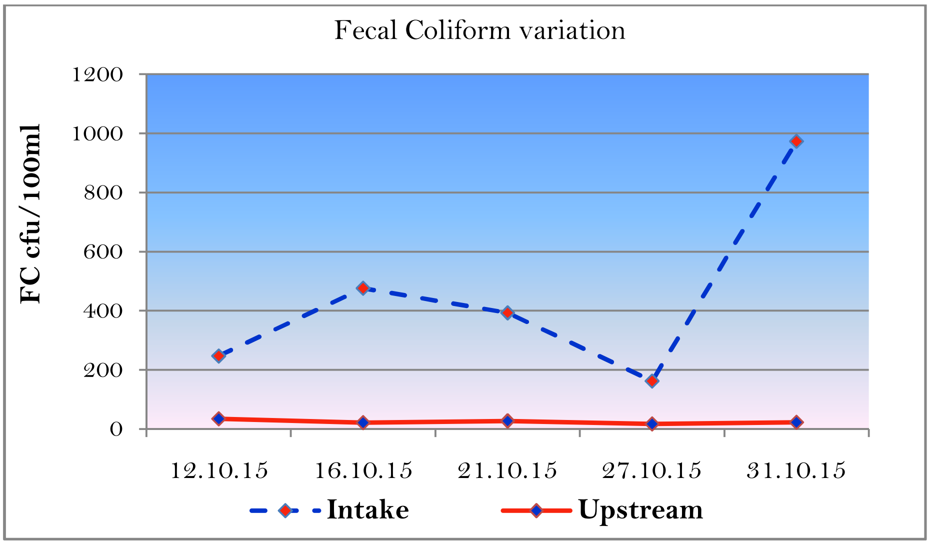

Figure 8:Feacal coliform concentration at intake and upstream

4.5 Dependent variables

4.5.1 The quality of treated final water abstracted from Nabajjuzi River and treated at the water treatment plant in Masaka District.

Final water samples were taken from Masaka water treatment plant. Results of analysis of final water samples were assessed in comparison to safety standard for potable water as stated in the Uganda National Standard for Potable water. Table 6 below indicates safety standards for the respective parameters analyzed to assess the quality and safety of Masaka final water.

Table 6: National Standard for Potable Water

National Standard for Potable Water	
Parameter	**Safety range**
Colour (PtCo)	0.0 - 15
Turbidity (NTU)	0.0 – 5.0
pH Value	6 .0 - 8.5
Iron total (mg/l)	0.0 - 0.3
Feacal coliform (cfu/100ml	0

4.5.2 The quality of treated final water in terms of colour and Turbidity

Results in table 7 below shows that for most samples had colour concentration in final water was above the safety standard. Average colour concentration of final water was 17 PtCo which is above the upper permissible limit by 2.0 PtCo units.

Turbidity results indicates compliance to the safety standard of 0 – 5 NTU in all the samples of final water analyzed throughout the study period. The results for colour and turbidity of final water from the treatment plant are presented in table 7

Table 7: Colour and Turbidity in final water.

Final water quality				
	Colour in Platinum Cobalt units		Turbidity in Nephelometric Turbidity Units	
Dates	Final Water	Safety Standards	Final Water	Safety standards
12.10.15	19	0 - 15	1.3	0 - 5
16.10.15	21	0 - 15	1.5	0 - 5
21.10.15	12	0 - 15	1.1	0 - 5
27.10.15	17	0 - 15	1.2	0 - 5
31.10.15	15	0 - 15	1.5	0 - 5
Avg	16.8	0 - 15	1.32	0 - 5
Remarks				

A graphical presentation of colour concentration in final water shows a trend fluctuating above and below the national safety standard for potable water. Turbidity trend shows consistent compliance since the trend remained below the national safety standard of potable water as shown in figure 9.

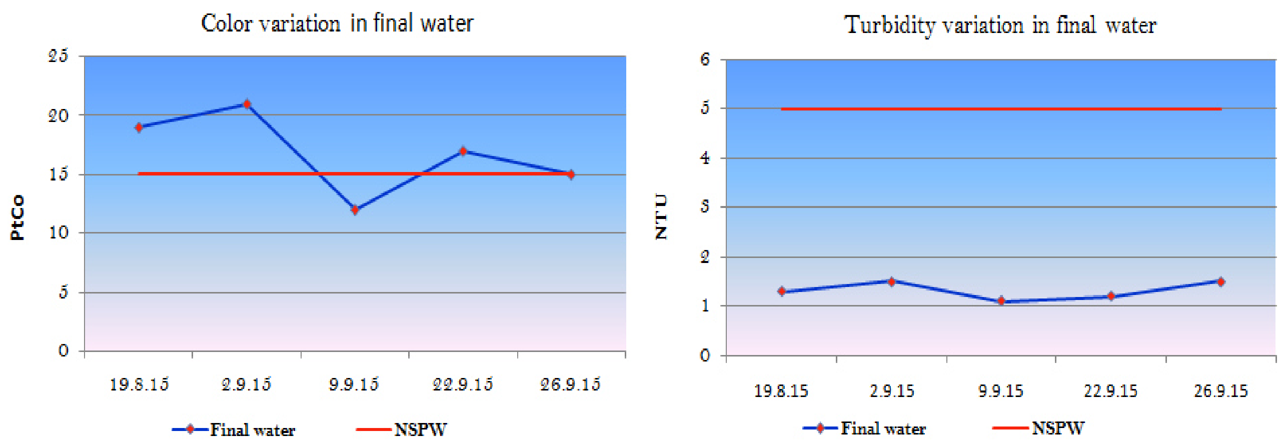

Figure 9: Colour and turbidity variation as compared with the NSPW.

Figure 13 indicated that colour remained above the standard for most time during the study period while turbidity was compliant to the NSPW of ≤ 5NTU throughout the study period.

4.5.3 Final Water Quality and Safety in terms of pH

pH of final water remained compliant in all samples taken and analyzed and the average pH also was within the required safety standard as indicated in the National standard for Potable water. pH value are presented in table 8 below

Table 8: pH value of final water.

Final water quality		
pH value		
Dates	Final Water	Safety Standards
12.10.15	7.4	6 .0 - 8.5
16.10.15	7.8	6.0 - 8.5
21.10.15	7.2	6.0 - 8.5
27.10.15	7.3	6.0 - 8.5
31.10.15	7.5	6 .0 - 8.5
Avg	7.44	6.0 - 8.5

A graphical presentation in figure 10 below indicated pH of the different samples fluctuating within the safety range required by the National Standard for Potable Water. The 2 red lines in the graph indicated the upper and the lower permissible limits.

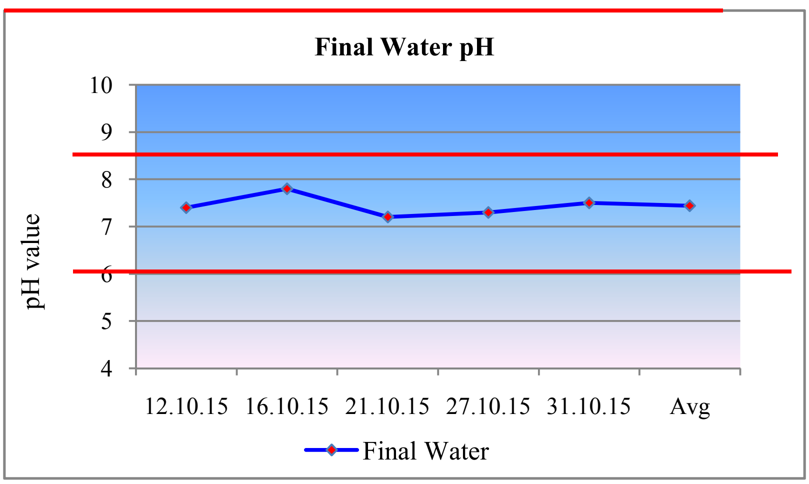

Figure 10: Variation of pH of final water

4.5.4 Iron Concentration in Final Water

Analytical results of final water quality regarding Iron indicated fluctuation with most values being above the safety standard thus making the average Iron concentration being above the safety requirement by the standard. The analytical results from Iron analysis are presented in table 9.

Table 9: Iron total result in final water

Final water quality		
	Iron total in mg/l	
Dates	Final Water	NSPW
12.10.15	0.27	0.0 - 0.3
16.10.15	0.97	0.0 - 0.3
21.10.15	0.47	0.0 - 0.3
27.10.15	0.73	0.0 - 0.3
31.10.15	0.28	0.0 - 0.3
Avg	0.54	0.0 - 0.3
Remarks		

A graphical presentation as shown in figure 11 below indicates Iron concentration trend fluctuating with values of most samples being above the safety standard making the average value failing to comply with the safety standard requirement of Iron total in potable water.

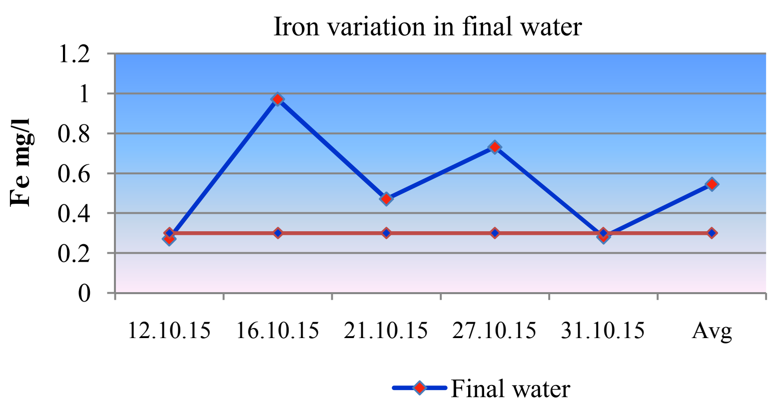

Figure 11: Iron concentration variation in final water.

4.5.5 Final water bacteriological quality and safety

Table 10 indicates that the bacteriological quality of final water complied with the safety standards in all final water samples tested. Results from feacal coliform bacteria analysis is presented in table 10.

Table 10: Table 12: Feacal coliform bacteria in final water

Final water quality		
	Feacal coliform bacteria in cfu/100ml	
Dates	Final Water	NSPW
12.10.15	0	0
16.10.15	0	0
21.10.15	0	0
27.10.15	0	0
31.10.15	0	0
Avg	0	0
STDV	0	
Remarks		

4.5.6 Free chlorine residual

Chlorine measurement at the treatment plant on final water samples were also done and in all samples, free residual chlorine was found to be between 1.00mg/l to 1.7mg/l in all the samples. (Appendix B)

4.6 Bivariate Analysis Results

4.6.1 Colour concentrations in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district

A statistical relationship on results of colour from upstream and intake samples along the Nabajjuzi River were tested using ANOVA single factor. Table 11 below, shows the P-value

0.014997 to be lower than the α of 0.05. *F* value and *F. Critical* are 11.37340062 and 5.987377584, respectively. A consideration of the P-value, *F* and *F Critical* all indicated significant level of difference exists between colour concentration before and after the untreated spent filter discharge point along the Nabajjuzi River.

Table 11: ANOVA table for comparing colour before and after SFBW discharge point.

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Intake	4	1964	491	38870		
Upstream	4	628	157	364		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	223112	1	223112	11.3734	0.014997	5.987378
Within Groups	117702	6	19617			
Total	340814	7				

4.6.2 Turbidity concentrations in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district

Turbidity concentration at the two sampling points along Nabajjuzi River before and after the untreated spent filter waste discharge points was statistically tested and results in table 12 indicates there exists a significant difference. *F* value was 18.96214283 and *F. Critical* was 5.987377584, and α value of 0.05 with a *P-value* of 0.004798776.

Table 12: ANOVA table for comparing turbidity before and after SFBW discharge point.

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Intake	4	70.5	17.625	19.0425		
Upstream	4	32.44	8.11	0.0556		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	181.0705	1	181.0705	18.96214	0.004799	5.987378
Within Groups	57.2943	6	9.54905			
Total	238.3648	7				

4.6.3 pH values in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district

Results of pH values from upstream and intake point indicated no statistical difference on ANOVA test. From table 13 below, *F statistics* and *F critical* are 1.420085 and 5.987378 respectively while P and the α value are 0.278383 and 0.05 repectively.

Table 13: ANOVA table for comparing pH before and after untreated SFBW discharge point.

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Intake	4	23.98	5.995	0.633433		
Upstream	4	21.75	5.4375	0.242025		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.621613	1	0.621613	1.420085	0.278383	5.987378
Within Groups	2.626375	6	0.437729			
Total	3.247988	7				

4.6.4 Iron concentration in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district

Iron concentration in samples from upstream and intake were tested for statistical relationships. Table 14 below indicates the *P and the* α *values* of 0.005269 and 0.05. *F* value and *F. Critical* were 14.40747 and 5.317655 respectively. A consideration these statistical determinants indicated significant level of difference between Iron concentration at upstream and intake points along the Nabajjuzi River.

Table 14: ANOVA table comparing Iron concentration before and after untreated SFBW discharge point.

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Inake	5	89.3	17.86	25.7672		
Upstream	5	45.43	9.086	0.94918		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	192.4577	1	192.4577	14.40747	0.005269	5.317655
Within Groups	106.8655	8	13.35819			
Total	299.3232	9				
Alpha value 0.05						

4.6.5 Feacal coliform concentration in raw water before and after the spent filter backwash water discharge point along Nabajjuzi River in Masaka district

Feacal Coliform bacteria in samples from upstream and intake were tested for statistical relationships. Table 15 below indicates the *P and the* α *values* of 0.030918 and 0.05. *F* value and 7.873755 and 5.987378 respectively. A consideration of these statistical determinants indicated significant level of difference between Feacal Coliform bacteria concentration at upstream and intake points along the Nabajjuzi River.

Table 15: ANOVA table comparing feacal coliform concentration before and after untreated SFBW discharge point.

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Intake	4	2004	501	116664.7		
Upstream	4	87	21.75	16.91667		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	459361.1	1	459361.1	7.873755	0.030918	5.987378
Within Groups	350044.8	6	58340.79			
Total	809405.9	7				

CHAPTER FIVE:

DISCUSSION OF RESULT

5.1 Introduction

This chapter discusses the research findings in relation to the problem statement, specific study objectives and in line with the literatures reviewed. It also explains the results from the study carried out.

Raw water test results on samples taken before the spent filter backwash discharge point (upstream) are discussed first followed by raw water tests results on samples taken after the spent filter backwash discharge point (Intake) and final water quality test results in comparison to safety standard as indicated in the Uganda National Standard for Potable are discussed last.

5.2 Colour and turbidity concentrations in raw water form upstream and intake points along Nabajjuzi River in Masaka district.

5.2.1 Colour

Colour at upstream was averagely 68.5% lower than colour values from intake point 2. This addition of color in the raw water at point 2 resulted from the discharge of untreated SFBW which is in agreement with causal factors explained by Edzwald, Tobiason et al., (1999). Standard deviation analysis also indicates color being more stable at point 1 (stdev: 16.8) as compared to point 2 (stdev: 172.6). This wide variation in colour concentration at intake corresponded to episodes of untreated SFBW discharge also explained by Edzwald, Tobiason et al., (1999) in his findings.

Further, Cornwell et al., (2001) explains that untreated SFBW contains high concentrations of solids in suspension, colour and bacteria; this may be one of the reasons dilution by the incoming raw water was not sufficient to effectively reduce colour at intake point.

A Statistical comparison by use of ANOVA single factor indicated a significant difference in color values between upstream sampling points and intake point. These differences are being caused by the untreated SFBW discharge as stated in Cornwell at el., (2001).
According to Water Research Foundation (2010), constructing an equalization tank to receive the SFBW would help to remove spikes as seen on sample of the 16th 10 2015 in figure 6 above. An equalization tank is kept at a constant mix to avoid settlement of solids and any other particulates so that waste going out of the equalization tank is of uniform quality. These units are missing in Masaka water treatment plant thus resulting into unstable quality of raw water at the intake point. This surges in raw water quality at intake causes stress on the performance of the different water treatment units resulting into low quality final water with regard to colour as explained by Edzwald, James et al., (2011).

5.2.2 Turbidity

Turbidity trend also shows similar characteristics to color; 55% lower turbidity values at upstream sampling point than at intake point. The variation in turbidity concentration was stable at point 1 with a standard deviation 0.20 while unstable at point 2 with standard deviation of 4.10. The differences in average turbidity concentrations and differences variation are caused by untreated SFBW discharge episodes explained in Edzwald, Tobiason et al., (1999). This is the very reason the AEPA put forth a regulation FBRR so that spikes like these do not end up in the treatment plant that will overwhelm the right chemical dosing set thereby compromising treatment efficiency as described in Edzwald, James K., et al., (2011).

Statistical comparison indicated significant difference in turbidity concentration before and after SFBW discharge confirming hypothesis 1 that SFBW is increasing turbidity concentration at intake point thus, it is clear that NWSC need to treat the spent filter water before recycling.

5.3 pH and Iron concentrations in raw water from upstream and intake points along Nabajjuzi River in Masaka district.

5.3.1 pH

pH remained relatively stable in both sampling sites even with discharge episodes of untreated SFBW. Statistical comparison did not show any significant variation either. However; it is noted that raw water pH before the discharge was quite acidic 5.4 and after the discharge the average when up to 6.0 this was possibly due to the residual coagulant in the recycled untreated waste but did not make any significant difference on pH values between the two raw water sampling points. This finding is not in conformity with the general principles shown in a number of publications reviewed herein like Edzwald, Tobiason et at., (1999), Edzwald, James K., ed. (2011) indicating general increase in all parameters on raw water as a result of recycling untreated SFBW.

5.3.2 Iron

Iron concentration at upstream point was lower by 49% than in intake samples. Fluctuation in iron concentration was lower at upstream point (stdev: 1.0) while point 2 showed very unstable iron concentration (stdev: 5.1). This finding agrees with the study carried out by Isagara et al., (2012) stating challenge of high iron concentration in raw water requiring chemical pre-oxidation. This finding reveals that the source of this high Iron concentration in the raw water at intake point can be traced to the recycling of the untreated SFBW which is in concomitance with findings stated by Cornwall et al., (2001). Statistical comparison further confirms that significant difference does exists in iron concentrations between these two points.

5.4 Feacal coliform bacteria concentrations in raw water from upstream and intake points along Nabajjuzi River in Masaka district

Concentration of fecal coliform at intake point increased by 94.6% than in upstream point. Cornwell et al., (2012) found concentration of bacteria in untreated SFBW to be anywhere between 16 – 20 times higher than in the corresponding raw water this was the case as in Masaka where feacal coliform concentration at intake was found to be 18 times higher than in the upstream point shown in figure 8. According to USEPA this high concentration of bacteria creates the need for treatment of SFBW to reduce such concentration of bacteria in the SFBW to be equal or lower than the corresponding raw water otherwise the danger is that a the treatment plant's pathogenic removal processes will not be adequate to protect the public, and some dangerous organisms will be released into the treated water; Edzwald, James K., et al., (2011).

A statistical analysis indicated a significant difference in feacal coliform concentration between the two raw water sampling points. The differences in feacal coliform concentration between the two raw water sampling points is attributed to by the concentrations of bacteria in the untreated SFBW and peaks shown in figure 9 corresponds to discharge episodes stated by Edzwald, James K., et al., (2011).

5.5 The quality of final water treated at Masaka treatment plant abstracted from Nabajjuzi River after untreated SFBW discharge point

Final water quality was assessed to establish whether recycling untreated SFBW affected final water compliance to safety standards for public health consumption with regards to the National Standard for Potable Water. Assessment was based on compliance of colour, turbidity, pH, iron and fecal coliforms bacteria to safety requirement.

5.5.1 Colour

Table 11 indicated average color value being 17 PtCo this was above the safety requirement for Potable Water (UNSPW). Figure 13 showed colour values remained above the standard most parts of the study period thus indicating failure of the treatment system to effectively and consistently keep color values within the required limit of ≤15 PtCo units. This is well explained by Edzwald, James et al., (2011) that lack of treatment of SFBW will result into spikes of high colour in final water which corresponds to each discharge episode henceforth confirming hypothesis 1 proposed raw water colour at intake affected colour in final water.

When erratic changes like this occur in raw water quality, optimum polymer dose should correspondingly be changed and when this is not changed, the corresponding effect is under chemical dose resulting in high color in final water that will not meet the required safety standard stated by Edzwald, James et al., (2011). To cope with such sadden change in raw water quality caused by discharge episodes of untreated SFBW, frequent adjustments of chemical coagulants is needed and when this is not done final water colour quality is compromised.

USEPA (2010) indicated that untreated SFBW has the potential of affecting water treatment plant efficiency and therefore untreated SFBW must be treated prior to recycling and this is evident in the unstable colour of final water at Masaka water treatment plant. As hypothesized, increase in raw water colour at intake resulting from recycling untreated SFBW caused colour of final water failed to meet safety requirement of the National Standard for Potable Water.

5.5.2 Turbidity

The average turbidity of final water was 1.3NTU which was within the required safety standard of ≤ 5NTU. All samples taken during the study period also complied with this safety requirement however, according to USEPA (2010), if untreated SFBR is being recycled, turbidity in final water must be kept below 1 NTU to eliminate any chances of bacterial slip through into final water; Masaka final water would have failed to measure up to this requirement. Hypothetical prediction 1 regarding turbidity did not hold in this case; raw water turbidity at intake did not affect final water turbidity compliance to safety standard

5.5.3 pH

Final water quality regarding pH was compliant to safety requirements stated in the National Standard for Potable water in all the samples analyzed.

5.5.4 Iron total

Figure 14 indicated average concentration of iron as 0.54mg/l in final water this was above the recommended safety limit of 0.3mg/l as per NSPW. Figure 8 had shown that the untreated SFBW was significantly adding iron into the raw water at intake point this same finding was presented by Isagara John Paul et al., (2012). This provides evidence that recycling of untreated SFBW is compromising treatment efficiency regarding iron removal thus final water Iron failing to meet the Uganda National Standard for Potable as discussed in the USEPA (2010) about the effects of recycling SFBW without treatment. Hypothesis 2 predicted correctly that recycling untreated SFBW will cause final water Iron content not to comply with the safety requirements.

5.5.5 Feacal Coliform Bacteria

The Uganda National Standard for Potable Water requires that potable water should have zero Colony Forming Units per a hundred mills of final water (0 cfu/100ml). Analysis of final water from the treatment plant indicated consistent compliance to this requirement in all the samples collected and analyzed. This also indicated that despite the high levels of faecal coliform bacteria in raw water at intake point resulting from recycling of untreated spent filter backwash water, treatment in form of chlorine disinfection was effective in removing all faecal coliform bacteria. However, it should be noted that there are a number of pathogens that are resistant to chlorine disinfection like clostridium pafringens and Cryptosporidium which were not tested for in this study.

The fears of possible feacal coliform bacterial remaining in final due to recycling untreated SFBW as stated by Edzwald, James et al., (2011) did not prevail in Masaka thus, Masaka final water was bacteriologicaly found to comply to water safety requirement for public health consumption; this finding disagrees with what hypothesis 3 predicted.

5.5.6 Free Chlorine Residual

According to the USEPA (2010), free chlorine residual between 0.2mg/l – 0.5mg/l should be maintained in the distribution for at least four consecutive hours. Chlorine measurement at the treatment plant was done and found to be above 1.00mg/l in all the samples taken during the sampling campaign (appendix A). This high concentration of chlorine at the treatment plant was to cater for decay along the distribution so that by the forth hour, chlorine residual of 0.2mg/l in the distribution is still available.

5.6 Safety of final water in Masaka District

Analysis of all final water samples treated at Masaka Water Treatment Plant indicated that colour and Iron were above the National Standard for Potable Water. This high colour was possibly due to residual iron detected in final water. However, these are aesthetic parameter and the concentration of iron detected in final water is not toxic but rather imparts colour in final water as stated by Kemker, Christine et al., (2013).

Turbidity, pH and bacteriological quality of final water consistently complied with all safety requirement of the Uganda National Standard of Potable Water. This finding on final water confirms the 4th hypothesis about Masaka final water complying to safety requirements of potable water

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter highlights the findings in form of conclusions and recommends what needs to be done with regards to the study objectives and also proposes areas of further research.

6.2 Conclusions

Effects of recycling untreated SFBR on quality of raw water at intake point: Comparison of results of analysis of raw water samples from the two sampling points (upstream and intake) indicated a significant increase in Iron, Turbidity, Colour and Feacal coliform concentrations at the intake point relative to upstream point.

Effects of recycling untreated SFBW on quality and safety of final water: This study has confirmed that the increase in concentrations of these physio-chemical parameters at intake point is a result of recycling untreated spent filter backwash water. This discharge of untreated SFBW is curtailing the treatment plant's ability to effectively and consistently keep colour and iron concentration of final water within final water safety requirements.

Turbidity, pH and bacteriological quality of final water complied to the safety requirement of Uganda National Standard for Potable Water in all the samples of final water analyzed. Since colour and Iron parameters contribute to aesthetic property of water, these parameters in themselves don't pose any health risks at the concentrations detected however; they make the water offensive to site thus, it is safe to conclude that Masaka final water is safe for public health consumption.

6.3 Recommendations

With regards to the objectives of the study and the conclusions drawn, it is safe to make the following recommendations.

Constructing an equalization tank and a quiescent tank would go a long way in reducing the concentrations of the different parameters measured which would significantly reduce loading to the treatment plant. This will not only reduce on the chemicals being used for treatment but reduce the stress on the treatment plant thus improving treatment efficiency of each unit.

The second alternative is the use of a dewatering press to remove all the solids and allow only the liquid to be recycled. This equipment also serves the same purpose of reducing organics in suspension and bacterial loading.

Another feasible option is to perform some civil engineering maneuver to divert the spent filter backwash water to discharge downstream the current raw water abstraction point though this would still tantamount to an environmental negligence.

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www.alliance2015.org/index.php/news/content/download/114/466/file/mdg.pdf

APPENDICES.

Appendix 1: Introduction letter

IHSU INTERNATIONAL HEALTH SCIENCES UNIVERSITY
sanitas per scientiam

making a difference to health care

Dean's Office-Institute of Public Health and Management

Kampala, 7th October 2015

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Dear Sir/Madam,

RE: ASSISTANCE FOR RESEARCH

Greetings from International Health Sciences University.

This is to introduce to you **Araa John Kennedy, Reg. No. 2013-MPH-PT-014** who is a student of our University. As part of the requirements for the award of a Masters Degree of Public Health, the student is required to carry out field research for the submission of a Research Dissertation

Araa would like to carry out research on issues related to: **Assessment of Water Quality at Masaka Water Treatment Plant in relation to Uganda National Standard for Potable Water**

I therefore request you to render the student such assistance as may be necessary for his research.

I, and indeed the entire University are thanking you in anticipation for the assistance you will render to the student.

Sincerely Yours,

07 OCT 2015

Alege John Bosco

Ag. Dean, Institute of Public Health & Management

Ag Dean IHSU
We have reviewed the proposal and the work is very relevant to NWSC. We have cleared him to conduct the study
Dr. Mbabu
OCT 2015

THE CENTRAL LABORATORY

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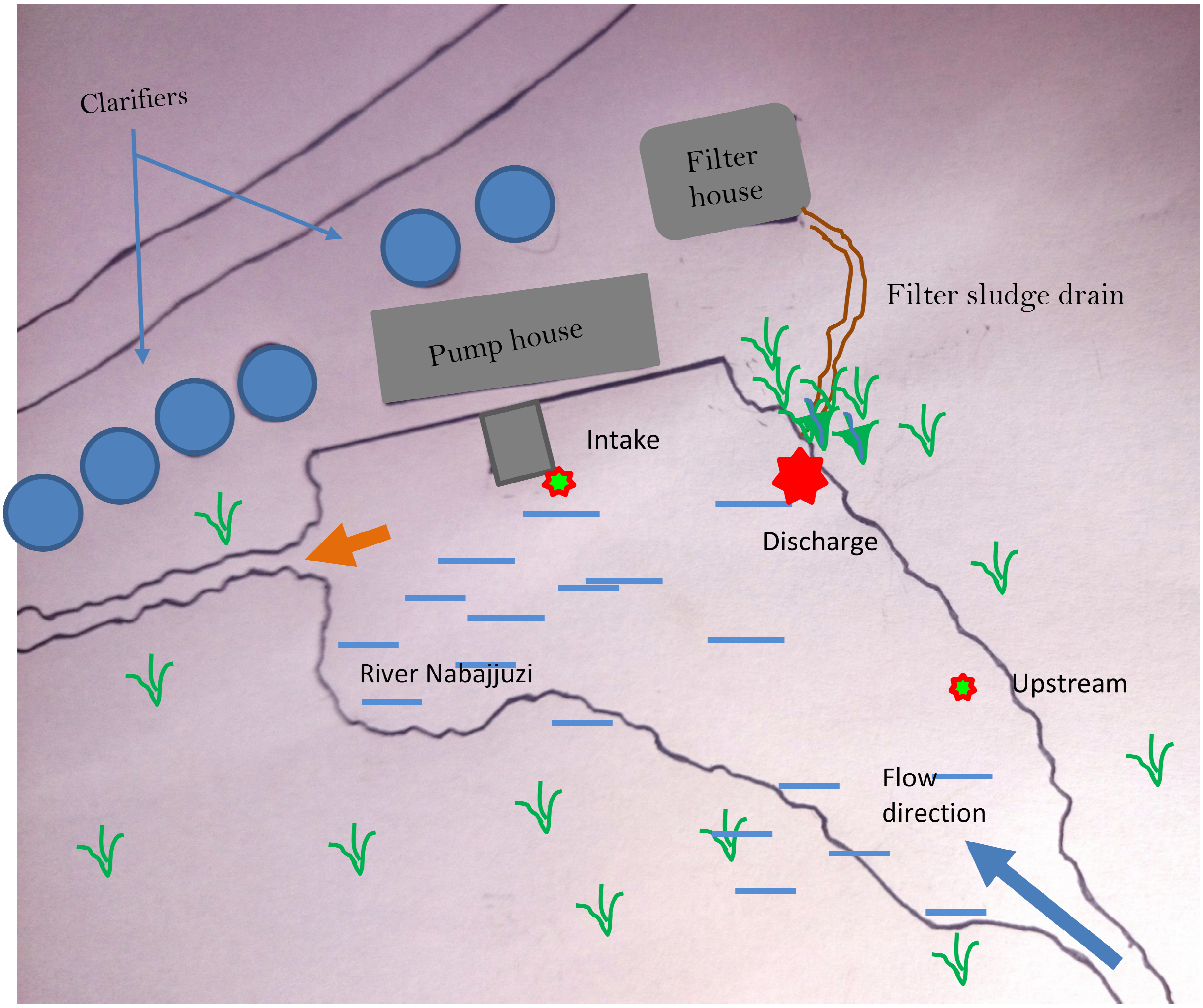
Appendix 2: Masaka NWSC - sludge discharge point, sampling points 1 & 2



Appendix 3. Using Turbidity meter to analyse turbidity