ASSESSING THE SUITABILITY OF A WASTEWATER EFFLUENT REUSE IN APPLICATION OF NON-POTABLE USE

DOMINIC LOKWANG

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ABSTRACT

This project addresses the problem of high-quality potable water being used to carry out low quality tasks such as flushing in toilets and urinals by offering an affordable, yet environmentally friendly way of harnessing treated wastewater effluent for non-potable applications. This research aims to assess the raw quality (physicochemical and microbiological characteristics) of treated wastewater effluent from the UCU wastewater treatment plant and treat it with reference to how it complies with established reclaimed water standards for use in toilet and urinal flushing.

Uganda Christian University (UCU) purchases large volumes of potable water from National Water and Sewerage Corporation (NWSC) on a monthly basis. This water is used to ensure smooth running university activities such as cleaning, cooking, drinking, and waste management. Studies show that about 20-40% of domestic water demand is consumed in toilet flushing and 50-70% of commercial water demand (Ilemobade *et al.*, 2012).

DECLARATION

I, **LOKWANG DOMINIC** with registration number **M22B32/021** hereby declare that this is my original work, is not plagiarized and has not been submitted to any other institution for any award.

Student's name: LOKWANG DOMINIC

Sign: ……………………………………………………. Date: ……………………………………………

APPROVAL

This research project report submitted by **LOKWANG DOMINIC** to the Department of Engineering and Environment at Uganda Christian University has been carried out and compiled under constant supervision.

Eng. Prof. ELEANOR WOZEI

Academic Supervisor (Uganda Christian University)

Signature: …………………………………….

Date: …………………………………………….

DEDICATION

This report is dedicated to my brother as well as the father Dada Ross Romano, my wife Sagal Kevin and my children Dada Jerome, Nading Davin and Lopeyo Darius for their constant love and support throughout my education journey and through every season of my life thus far. This research is a testament of your loving guidance and perseverance to shape me into valuable citizen of this country. I am grateful for the sacrifices and investments you have made for my future.

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I give all glory and thanks to God Almighty for His boundless grace, wisdom, and strength throughout the length of my academic life. without His guidance and favors, it would have been impossible to complete this study. In times of doubt and uncertainty, His presence was my hope and strength.

I am highly grateful to my parents/supporters especial Dada Ross, Lokwang Alfred, Baatom Ben Koryang Nasur Charles, Lodung Francis, Bilamoe Reymond, Lopeyo Simon Nading and Bwire Paul Wafula my research partner) for their unlimited love, kindness, and sacrifices, their guidance and belief in me have been the foundation of my quest for studies. Their encouraging words and blessings have been the driving force that has helped me get to this milestone, and I will forever be thankful for their contribution to my life.

I would also like to express my sincerest thanks to my supervisor, Eng. Prof. Eleanor Wozei, for her invaluable guidance, patience, and constructive criticism throughout the duration of this study. Her professionalism and dedication not only had an impact on the quality of this research but have compelled me to grow academically and personally too. In a special way, I thank my project partner Lokwang Dominic for his continuous contribution and support in the making of this research.

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LIST OF ACRONYMS AND ABBREVIATIONS

AWWTP.................................... Activated Waste Water Treatment Plant

BOD.. Biochemical Oxygen Demand

CAPEX.....................................Capital expenditure

DF...Discounting factor

DN...Nominal diameter

HDPE...High density pipe

LPS... Liters per second

NWSC...................................... National Water and Sewerage Corporation

TPV... Total present value

UF... Ultrafiltration

US EPA................................... United States Environmental Protection Agency

O&M...operation and maintenances

PI.. Profitability index

PUB... Public Utilities Board (in Singapore)

PN...Nominal pressure

UCU...Uganda Christian University

U-PVC......................................Unplasticized polyvinyl chloride

UV.. Ultraviolet (radiation)

VOCs...................................... Volatile Organic Compounds

WHO…………………………………. World Health Organization

CHAPTER ONE: GENERAL INTRODUCTION

1.0 BACKGROUND

Uganda Christian university is currently using high quality potable water for non-potable use in toilet and urinals, irrigation leading to incorrection use of treated water consequently the university incurs a substantial burden due to its dependence on potable water supplied by national water and sewerage corporation. Over the last years, UCU spent between UGX 30million and UGX 40 million per month on potable water, equivalent to approximately 6000 to 7000 cubic meters monthly (Mangene, 2025)

Implementation of a wastewater effluent reuse would reduce the demand of potable water hence enhance sustainable environment by reducing volume of treated effluent discharged to environment.

UCU activated wastewater treatment plant was commissioned in 2006 the first facility of it is kind in Uganda, it handles wastewater generated from the university residences including cooking, cleaning, washing and human waste management.it waste constructed to support on decentralized waste management, wastewater from toilet, showers and laundry areas is processed through a treatment system consisting of solid waste removal biological decomposition and chlorination. Influent from campus activities is converted to treated effluent that is safe for discharge into environment.

1.1.0 PROBLEM STATEMENT

Uganda Christians university currently relies on potable water for non potale uses such as flushing toilets and urinal plus irrigation resulting to inefficient allocation of quality water, as potable water is being used for task that do not reuire such standards the practice is unsustainable and contribute to unnecessary strains on the university`s water resources. UCU Has it`s financial burdens incurred to NWSC for low grade over a period of five years, ucu has consistently spent between thirty million to forty million with equal volume of treated water of 6000 cubic metre to 7000 cubic meter monthly

Implementation of a wastewater effluent reuse would reduce the demand of potable water hence enhance sustainable environment by reducing volume of treated effluent discharged to environment.

1.1.1 MAIN OBJECTIVES

To Assess the suitability of a wastewater effluent reuse in application for non-potable use

1.1.2 SPECIFIC OBJECTIVES

1. To determine the physicochemical and bacteriological characteristics of UCU effluent.
2. Determine the quantity of effluent discharge and design a non-potable water distribution system
3. To conduct a comprehensive cost benefit analysis of the wastewater effluent reuse.

1.1.3 RESEARCH QUESTIONS

1. What are the physicochemical and bacteriological characteristics of raw UCU effluent.
2. What is the amount of effluent discharge from wastewater treatment plant.

3. What is the cost-benefit analysis of the wastewater effluent reuse system.

1.1.4 JUSTIFICATION

INTRODUCTION

Institutions typical have high demand on water usage leading to substantial economic burdens due to the large volumes of water required for daily operation, application .at Uganda Christian university, this challenge is intensified by the misallocation of high-quality drinking water paid to National water and sewerage corporation at a cost of 30 million-40 million with equal volume of 6000-7000 cubic m most of this water is used for sanitary use. As a result of significant and continuous increasing financial expense, limiting the effective and suitable management of its potable resources.to address the problem, the university must adopt an alternative water source capable of serving the non-potable appliances

Globally, many institutions facing similar challenges have successfully implemented wastewater reuse system (PUB, 2014). The approach involves treated wastewater to acceptable standards for non-potable uses such as toilet flushing, landscape irrigation and industrial cooling of equipment. Wastewater reuse has proven effective inclosing the water loop and reducing dependence on potable water supplies.

1.1.5 CONTENT SCOPE

This research is focused on determining the suitability of a wastewater effluent reuse system for non-potable applications in Uganda Christian University. This study strives to treat and compare effluent produced by the Uganda Christian University activated wastewater treatment plant to the guidelines of treated wastewater effluent quality for non-potable use (toilet and urinal flushing).

1.1.6 GEOGRAPHICAL SCOPE

This study is to be carried out in Uganda Christian University in the Activated Wastewater treatment plant.

TIME SCOPE

This research project commenced in June 2025 and will be completed in December 2025.

CHAPTER TWO: LITERATURE REVIEW

2.0 INTRODUCTION

Review gives information on the current research on the use of wastewater effluent for non-potable applications such as flushing in toilets and urinals, irrigation, and cooling of machinery in industries to mention but a few.

The treatment and reuse of wastewater effluent for non-potable applications is an admirable strategy used to conserve potable water supplies in urban areas. The initial stage is the treatment of the wastewater effluent to meet non-potable water quality standards for toilet flushing. This is to reduce the risk human contamination and user acceptance of the project. This can reduce the demand for potable water in a community (Pandey, 2022). When wastewater effluent is incorporated into waste management, there is a closed loop in which water is transformed from a discharged waste into a precious resource.

2.1.1 Physicochemical and Bacteriological Characteristics Ucu Wastewater Effluent

Ucu Effluent Quality

Effluent quality refers to the chemical, physical, and biological characteristics of the effluent generated by the UCU wastewater treatment plant in regards to the intended use. For water to be acceptable for use by the population, there must be no risk of disease contraction by the users and an aesthetically acceptable outlook of the reused water.

A total of six water quality parameters were selected for this study (PUB, 2014). They include:

a) Turbidity.

The turbidity of effluent indicates the presence of suspended particles in the effluent. Filtration is type of treatment widely used to reduce turbidity of water. in this process, the wastewater effluent is passed through the porous medium to remove particulate matter (J. Shanthi Sravan, Leonidas Matsakas and Sarkar, 2024). Membrane technologies used include; microfiltration and ultrafiltration which are used for advanced wastewater treatment because they are effective in removing micron sized particles.

, preventing salt water (seawater) contamination and augmenting the region's drinking water supply. Another technology widely used in wastewater filtration is sand filtration. Larger suspended particles like silt are physically trapped in the spaces or pores between the sand grains as wastewater trickles through sand layers. In addition, through the process of adsorption, small colloidal particles that pass through the sand's pore spaces are trapped by adhesion on the surface of the sand grains.

a) Color.

Color is an important physical parameter that informs about the wastewater effluent composition, condition, and potential contaminants therein.

In the treatment of wastewater effluent, chemical methods of treatment are often employed. The coagulation and flocculation processes are widely employed because they are highly effective in the decolorization of water (Ho, Chua and Chong, 2020). This involves the addition of chemical coagulants to destabilize the suspended particles and colored compounds in the wastewater effluent.

In the treatment of wastewater effluent, it is crucial to have a neutral pH. This is because extreme pH values are fatal to both aquatic life and cause damage to the piping and plumbing systems in place aimed towards the reuse of effluent (El-Khateeb, Nashy and Nayl, 2020).

The fundamental principal in pH correction is the addition of an acidic or basic chemical to adjust the pH of the wastewater effluent to a neutral range. For example, between 6.0 – 9.0.

b) Total coliforms

Total coliforms are a group of bacteria that are no exactly harmful, however their presence in wastewater effluent indicates the presence of certain disease-causing microorganisms. Total coliforms are found in all parts of the environment such as the soil, in vegetation, and in the guts of warm-blooded animals (Solomon Oluwaseun Akinnawo, Peter Odunayo Ayadi and Mathew Temitope Oluwalope, 2023).

Chlorine is widely used as a disinfectant because it disrupts the microbial cell membranes and inactive enzymes crucial for cell survival of the bacteria. The effectiveness of the chlorination by chlorine depends largely on the chlorine dosage, contact time, pH, and the presence of other interfering substances.

c) Escherichia coli (E. coli)

E. Coli is a common bacterium found in the intestines or gut of warm-blooded animals, including humans. The presence of e. coli in wastewater effluent indicates fecal contamination, and the presence of pathogenic microorganisms that are a health risk to the public and to the environment (Pallavali, Shin and Choi, 2023).

E. Coli and other pathogens can also be treated using chemical disinfection with chlorine disinfection being one of the most used methods. Another method is ozonation where ozone, a powerful oxidant and disinfectant is used to inactivate microorganisms. In some cases, ozonation is preferred because of its ability to disinfect without forming harmful disinfection byproducts (Solomon Oluwaseun Akinnawo, Peter Odunayo Ayadi and Mathew Temitope Oluwalope, 2023).

d) BOD_5

Biochemical oxygen demand over 5 days is an important parameter to determine the quality of the wastewater effluent. The concentration of BOD_5 in water is indicative of the level of organic pollution present in the water. It is used to quantify the amount of dissolved oxygen consumed in the decomposition of organic matter by microorganisms (Maddah, 2022). Presence in organic pollutants in wastewater effluent increases the risk to human health if this effluent is reused for toilet flushing.

2.1.2 Case Studies of Implemented Wastewater Effluent Reuse Systems

Water Factory 21, Orange County California

Water factory 21 is a large-scale ground water recharging facility located in Fountain Valley, Orange County California. It was founded by the Orange County Water District to augment and protect the scarce groundwater aquifers from seawater intrusion. The ground water aquifers in Orange County faced a problem of the drop of groundwater levels caused by the over excavation of groundwater and the intrusion of seawater into the aquifers. The solution employed is the use of municipal sewage effluent generated by approximately 2.5 million residents to recharge the groundwater aquifers. The first objective was to treat the secondary effluent to a high quality for injection in to the ground (OCWD, 2018).

A tertiary treatment train was used to treat the secondary effluent which involved lime clarification, carbon adsorption, reverse osmosis, and chlorination as a multi-barrier treatment train. This treatment was focused on meeting drinking water quality standards. Injection wells were used to deliver the highly treated water into the aquifer, which then served as a natural storage and distribution reservoir

Results showed that the Water Factory 21 provided a high-quality Groundwater Replenishment System, a supply system that can trace contaminants, and long-term water security in a semi-arid region.

2.1.3 Sembcorp NEWater plants, Singapore

The Sembcorp NEWater plant is the world’s largest water reclamation plant operated by the Public Utilities Board of Singapore. It has a capacity of 228,000 cubic meters per day. The challenge of water scarcity and national security have been vital in the driving of Singapore’s NEWater program which has been a vital initiative ever since its establishment because the country previously relied on imported water. Therefore, to diversify the nation’s water supply the scheme began to treat secondary effluent generated from the comprehensive sewerage network of the Island known as the Deep Tunnel Sewerage System (PUB, 2018). The non-potable applications considered are: flushing of water closets and urinals, general washing, irrigation, and cooling-tower make-up.

Figure 1: Sembcorp NEWater Plant in Singapore (Changi Water Reclamation Plant & Sembcorp NEWater Plant, 2023)

The NEWater plants a treatment system that comprises of three stages to make the effluent reach non-potable water quality standards as per their PUB guidelines. They include:

a) Microfiltration or ultrafiltration to remove suspended solids and colloids.
b) Reverse osmosis to remove viruses and salts.
c) Ultraviolet disinfection and chemical disinfection.

NEWater facilities produce tens to hundreds of millions of gallons of water per day in aggregated capacity and significantly contribute to Singapore's water supply. A single plant is reported to meet approximately 12% - 15% of the water demand. The reported output it was discovered to have a very high microbial and chemical quality suitable for industrial reuse and other non-potable applications.

The distribution system comprises of a 'purple pipe' system that is used to deliver the treated effluent to the industrial facilities and the other non-potable water applications (Opening of Singapore's Fifth and Largest NEWater Plant, The Sembcorp NEWater Plant, 2025).

The system design and selection went on as follows. After the characterization of the wastewater effluent to be reused, the data collected was used to identify worst case loads, typical loads, seasonal loads, and shock loads. This enabled PUB to clearly define the feedwater quality. Afterwards, the boards used removal performance data for the candidate treatment technologies of interest (membrane filtration, reverse osmosis, ultraviolet disinfection, and advanced oxidation) which they often obtained from pilot plants, such as the 2000 full-scale demonstration plant which would establish the suitable treatment train to achieve their desired water quality. To set the target water quality, PUB referenced WHO and the US EPA to attain high water quality standards. The board created mass balance and removal requirements for each contaminant as well as calculated log reductions that the treatment process must achieve to produce the desired water quality of the effluent.

Informed by the pilot and baseline data, PUB selected the three-stage treatment train for NEWater mentioned above.

Arizona State University (ASU) Tempe Campus, USA

The Tempe Campus once faced the problem of heavy reliance on municipal water sources for non-potable applications which resulted in high operational costs and the need for water independence in an arid climate. The solution employed was the establishment of a wastewater effluent reusing system to offset the cost incurred due to the use of clean water for non-potable applications. The effluent is generated by the campus community (students, faculties, and staff residents) and nearby community (Tortajada, 2014).

The wastewater is obtained from the municipal secondary treatment plant back to the wastewater effluent reclamation plant on the Tempe Campus. The treatment methods used are typically sand filtration and chlorination to meet the strict health standards for non-potable uses. The distribution system employed consists of color-coded pipe networks (purple pipes) constructed within the campus grounds to distribute the treated wastewater effluent to large landscaping irrigation systems, athletic fields and most importantly, toilet and urinal flushing in academic buildings.

Coastal Metropolitan Area Schemes - Catalonia Spain

A Barcelona coastal metropolitan reuse scheme was developed to address seasonal water scarcity. In addition, they were also developed to reduce pressure on surface water and groundwater sources and to prevent seawater intrusion in the Llobregat delta aquifer. The scheme sources secondary effluent from the metropolitan wastewater treatment plants. The end uses of the effluent include agricultural irrigation, wetland restoration and the prevention of seawater intrusion through a barrier.

To meet district end-use water quality standards, the schemes use a four-stage treatment system. That is to say, filtration, advanced biological and chemical treatment, and finally disinfection. For the distribution system, bulk conveyance pipelines, pumping stations, and reservoirs designed to meet seasonal peak demands as well as the need to meet the intrusion barrier (Mujeriego *et al.*, 2008).

Figure 2: A Reclaimed water pumping station for instream flow and agricultural irrigation (Mujeriego et al., 2008).

Treatment Of Wastewater Effluent to Meet Non-Potable Water Quality

The tested parameters that did not meet the Singapore PUB guideline quality for non-potable water for toilet and urinal flushing are, turbidity, E. Coli, Total coliforms. This necessitates the use of a sequence of treatment units to polish the effluent and disinfect it to reduce the risk of microbial contamination of the users of the effluent reuse system.

To select the appropriate treatment method, the following were taken in to careful consideration;

a) What is the current quality of the effluent?
b) What is the target effluent quality?
c) What adjustment is desired in the effluent?
d) What sequence of unit processes is most suitable to achieve the desired effluent quality?

Turbidity

To polish the effluent and remove reduce its turbidity, a filtration unit is proposed to make the effluent more aesthetically acceptable.

Filtration in the process of physically removing suspended particles, solids, and other fine particles from a liquid as it passes through a permeable barrier or a porous medium that retain these particles and allow the liquid filtrate to pass through the filter medium (Yogafanny et al., 2020).

To select the type of filtration to be employed, the following technologies were identified and assessed basing on their capabilities, viability, and availability in Uganda

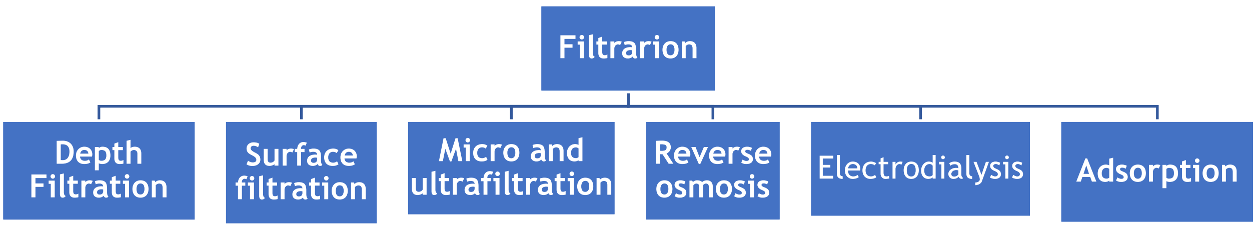


Figure 3: A flow chart showing the unit process technologies for removal of particulate matter from treated wastewater effluent (Metcalf & Eddy Inc. et al., 2014).

2.1.4 Depth filtration

This is a physical unit process that involves the physical removal of particulate matter and colloidal solids to a small extent from liquids passed through granular filter media. Depth filters operate by straining, sedimentation, interception, impaction, and adsorption (Metcalf & Eddy Inc. et al., 2014). A depth filter is the proposed treatment unit for polishing the wastewater effluent because of the principal mechanisms by which it operates.

The principal mechanisms by which depth filters remove particulate matter include;

a) Straining: where particles larger than the pores in the medium are trapped mechanically (Jiang et al., 2021).
b) Sedimentation: where heavy particles in the liquid settle on the filter medium.
c) Interception: when particulate matter in the liquid being filtered comes into contact with the surface of the filtering medium as is moves in a streamline.
d) Adhesion: which occurs when particles become attached to the surface of the medium as they pass through the filter.
e) Flocculation: occurs in the interstices of the filter medium where larger particles form due to the velocity gradients of the liquid as it is being filtered. Afterwards the particles are removed by any one of the above mechanisms.

2.1.5 Estimating the performance of a depth filter in the reduction of the turbidity of wastewater secondary effluent.

To determine whether a depth filter will be effective in the polishing of effluent from the UCU AWWTP, the following equation was employed to estimate whether the filtrate turbidity would meet the required turbidity quality of <2NTU.

Filter effluent turbidity, NTU = 0.5 NTU + 0.2 (Filter influent turbidity, NTU) (Metcalf & Eddy Inc. et al., 2014)

From the above calculation, a depth filter cannot achieve the desired turbidity (<2NTU). This could mean that either a depth filter is not an appropriate technology for this treatment, or another treatment unit can be employed to reduce the effluent turbidity before it is fed into the depth filter.

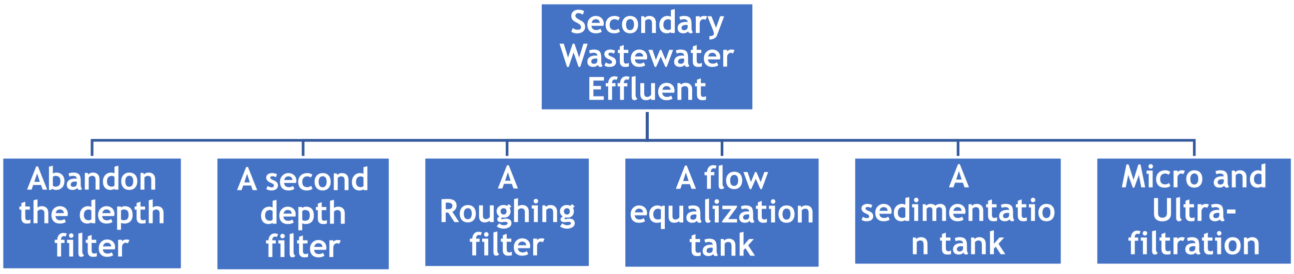


Figure 4: A flow chart showing options for the reduction of effluent turbidity

Theoretically, a second depth filter can reduce the effluent turbidity to a level that can be polished by a primary depth filter that meet the turbidity limit of <2NTU as shown in the calculation below.

Table 1: Estimating the performance of a second depth filter

Calculation	**Check**	**Comment**
Filter effluent turbidity, NTU = 0.5 NTU + 0.2 * 7.48 NTU = 0.5 NTU + 1.496 NTU = 1.996 NTU	Filter effluent turbidity, NTU = 0.5 NTU + 0.2 (Filter influent turbidity, NTU) (Metcalf & Eddy Inc. et al., 2014)	

E. COLI AND TOTAL COLIFORMS

To protect human health, the microbiological characteristics (E. Coli and total coliforms) will have to be treated to acceptable levels according to the Singapore Public Utilities Board non-potable water quality guidelines for toilet flushing.

The first step is to reduce the turbidity of the effluent because harmful pathogens can hide within the particles and suspended solids present in effluent rendering the disinfection ineffective.

Identified disinfection technologies include;

Chlorine dosing: dosing with chlorine involves the variation of dosage and contact time in order to determine the optimum dose that meets the chlorine demand in the effluent. This also entails determining the amount of residual chlorine required to continue disinfecting the non-potable water in the distribution lines.

For the purpose of disinfection, chlorine dosing will be employed in this research because it is a technology already in place at the UCU activated wastewater treatment plant to disinfect wastewater effluent.

Ultraviolet radiation (UV): This is a type of technology that is employed to deactivate disease causing microorganisms by damaging their genetic makeup. When ultraviolet light is incident on the cells of microorganisms, it damages the nucleic acid, i.e. DNA and RNA, which are necessary for their reproduction and multiplication (Pecson *et al.*, 2020). UV radiation kills all types of pathogens including viruses, protozoa, and bacteria. It is usually used in the disinfection of drinking water, wastewater, and water to be reused for various applications.

Factors to be considered for UV dosing for effective disinfection include; the exposure time of water to the radiation, the availability of

a) Water quality: Ultraviolet disinfection is only effective in water or wastewater effluent that has a low concentration of suspended solids, turbidity, and color (PUB, 2014).
b) UV transmittance
c) Residual disinfectant: UV disinfection does not provide residual disinfectant in the wastewater effluent. This necessitates the need for a chemical disinfectant such as chlorine to inhibit the growth the distribution system.

CHAPTER THREE: METHODOLOGY

3.0 INTRODUCTION

The reuse of treated wastewater (effluent) for non-potable applications (toilet flushing in particular) is a sustainable water conservation and resource management strategy. This chapter serves to provide an academic and scientific rationale for selecting key parameters to determine the physical, chemical, and biological parameters for the quality assessment of UCU's effluent which is intended to be reused for toilet flushing. The selected parameters are relevant to guaranteeing the safety, aesthetic acceptability, and long-term viability of a water reusing system. The selection is justified by their impact on human health, system longevity, and user acceptance.

There is no single, universal standard for non-potable water quality for flushing toilets. Instead, the standards for water reuse vary widely from country to country and are regulated by a "fit-for-purpose" approach, i.e., water quality is managed to be safe to use and to pose no hazard to public health and the environment.

Given that this research is taking place in Uganda, a country that experiences tropical climate and tropical weather patterns, the Singapore non-potable water standards for toilet and urinal flushing will be used to ensure the treated effluent meets public health standards for Uganda's climatic conditions. Singapore is located near the equator which results in a tropical climate with high temperatures and high humidity all year-long (Department of Statistics Singapore, 2025).

3.1.0 Determining the Physicochemical and Bacteriological Characteristics of Raw Ucu Effluent.

Effluent discharged into water or on land by any establishment must be treated based on the best practicable means, that is to say, environmentally sound practice and in compliance with the relevant guidelines (Standards for Discharge of Effluent into Water or on Land Regulations, 1999). National Environment Management Authority

Procedure for sample collection

1. Prepare the necessary equipment and apparatus for the field work. This includes sample collection containers and gloves. The containers are cleaned using distilled water to prevent any contamination of the raw sample.
2. The UCU AWWTP (sampling location) is then accessed with clearance from the plant operator. This is to ensure all project activities are authorized and do no cause alarm to the concerned officials of the plant. A 1.5L representative sample was obtained from the effluent discharge point in the UCU AWWTP. This procedure was repeated twice, once in the afternoon and once in the evening monitor any variation with in the day.
3. The sample was then transported to the UCU Environmental Quality Lab in a cooler box to protect it from sunlight.

3.1LABORATORY TESTS

3.1.0 Biochemical Oxygen Demand (BOD_5)

BOD_5 is a measure of the amount of dissolved oxygen in water required by microorganisms to aerobically breakdown (oxidize) organic matter present in a water sample with in a given period of 5 days. BOD concentration is indicative of the extent of organic pollution of the water or effluent in the case of this research. Water with a high BOD indicates a high concentration of organic pollutants.

Procedure

1. Collect raw effluent samples in clean sterilized containers.
2. Two BOD bottles were obtained and cleaned with distilled water.
3. 300ml of the collected samples were added into 2 BOD bottles. One for afternoon sample and another for evening sample.
4. 50ml of Sodium thiosulphate solution were added into each BOD bottle. The bottles were then shaken gently to evenly mix the solution.
5. Using a syringe, 1ml of manganese solution, sodium solution, and concentrated sulfuric acid were each added to the two samples in the BOD bottles and they are gently shaken to create a homogeneous solution.
6. The bottles are then left to settle for about 2 minutes.
7. Using a measuring cylinder, 100ml of each sample is added into a conical flask each.
8. Place each of the conical flasks under a burette and read off the initial readings of the sodium thiosulfate solution in the burette. Titrate sodium thiosulfate into each of the conical flasks until the solutions become colorless.
9. Read and record off the final burette reading.
10. Incubate the two BOD bottles at 35°C for 5 days.
11. After five days, repeat the procedure from step 5 to step 9.

12. The BOD_5 result is then calculated using the burette reading obtained.

The collected samples were taken to the UCU Environmental Quality Lab to determine the physicochemical and bacteriological characteristics of the raw effluent from the UCU wastewater treatment plant. The parameters were selected based on the Public Utilities Board (PUB), of Singapore because this country experience tropical climates like Uganda, with no distinct seasons like winter and summer, but rainy and sunny weather all year long with high temperatures and high humidity (Department of Statistics Singapore, 2025).

source of the effluent i.e. toilets and bathrooms in the halls of residence, staff quarters, lecture blocks, public sanitary facilities and the Janani Lowum dining hall in UCU.

3.1.1 COLOR

The effluent color is an aesthetic parameter that quantifies color imparted into water by dissolved substances (true color) and suspended materials (apparent color), indicating potential contamination and aesthetic issues (Omer, 2019). User perception is greatly dependent on the color of the effluent.

Procedure

1. The raw effluent sample is collected and inspected for its apparent color.
2. The effluent samples' color is determined using an optical apparatus by filling a blank with the sample until the bottom of the meniscus reaches the bottle's mark.
3. After inserting the blank into the apparatus, the read button is pressed. The color reading is taken and then recorded.

3.1.2 pH value

pH is the measure of how acidic or how basic the effluent is on a scale of 0 to 14.

The pH of the effluent is critical for the effectiveness of other treatment measures such as chemical disinfection through chlorination. pH also influences the potential for corrosion of pipes and fixtures.

Procedure

1. A standard buffer solution with established pH values was used to calibrate the pH meter.
2. The pH meter was used to determine the pH values of the raw effluent sample, then results were read and recorded.
1. The petri dishes are then incubated at 36ºC for 24 hours.
2. After 24 hours had elapsed, the petri dishes were removed from the incubator colonies were counted. The number of colonies formed was then taken as the E. Coli colony count.

3.1.3 Total coliforms

Measuring total coliform concentration in wastewater effluent is significant as they are a composite parameter of water quality and treatment efficiency. While E. coli particularly points towards fecal contamination, the total coliform group consists of bacteria from a more diverse array of environmental sources such as soil, plant material, and putrefying organic matter. Total coliforms are largely harmless, but their existence shows there is a pathway present for more dangerous pathogens to enter the system.

Procedure

1. A culture media is prepared by mixing 2.55g of violet red agar in 100ml of distilled water, and boiled for 2 minutes with continuous mixing until it completely dissolves. Sterilized petri dishes are then filled with the agar and allowed to settle so that the agar cools and solidifies.
2. The components of the membrane filtration are autoclaved to sterilize them and assembled afterwards.
3. The collected effluent sample is well shaken and 100ml of the sample is poured into the funnel.
4. After filtration, the sterilized forceps were used to place the filter paper in a violet red agar plate and then covered and labeled with the sample name.
5. The petri dishes are then incubated at 36ºC for 24 hours.
6. After 24 hours of incubation, the petri dishes were removed from the incubator and the number of colonies formed are counted and considered as the total coliform result.

3.1.4 E. coli

3. 2.55g of MacConkey agar is mixed with 100ml of distilled water and boiled for 2 minutes with continuous mixing to ensure all the agar is dissolved into the water. 10ml of the agar is then poured into sterilized petri dishes and allowed to cool.
4. The membrane filtration apparatus is then placed into an autoclave to sterilize them and assemble them afterwards.
5. The raw effluent sample is thoroughly shaken and 100ml of the sample is measured and poured in the funnel in the membrane filter.

6. After filtration, the funnel was removed and membrane filter paper was transferred to the MacConkey agar in the petri dishes using sterilized forceps.
7. The MacConkey agar plates are then covered and labeled with sample name.

3.1.5 TURBIDITY

Turbidity is a measure of the clarity of the effluent indicating the presence of suspended particles such as silt, sludge and inorganic matter. Turbidity is critical in this study because suspended solids in the effluent can create a hiding place for pathogens, protecting them from disinfection treatment methods such as ultraviolet (UV) light. The turbidity of raw effluent was measured using a turbidimeter instrument and the SI units are NTU (Nephelometric Turbidity Units).

Procedure

1. Using a standard calibration solution with known turbidity values, the turbidimeter is calibrated.
2. The raw effluent sample is collected from the effluent discharge point.
3. The effluent sample is then placed in a turbidimeter which determines the turbidity by measuring the degree at which light is scattered at 90^0 by suspended particles.
4. The result is then read and recorded from the turbidimeter in Nephelometric Turbidity Units.

Table 2: The parameters tested to determine the effluent quality (Public Utilities Board (PUB), 2014).

S/No.	Parameter	PUB guideline	Unit
1	Odor	Non offensive	
2	Color	<15	Hazen units
3	PH	6-9	
4	Turbidity	<2	NTU
5	BOD_5	<5	Mg/l
6	E. coli	Non detectable	CFU/100ml
7	Total coliform	<10	CFU/100ML

The sampling location is UCU Wastewater treatment plant in Mukono. The purpose of this sampling was to determine the characteristics of raw effluent which will inform the type of treatment required to meet the non-potable water standards for toilet flushing identified (Technical Guide for Greywater Recycling 1 st Edition: V2-Sep 2014). These guidelines were established to aid in the recycling of greywater for non-potable applications such as toilet and urinal flushing, general washing, irrigation, and cooling tower make up water.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 INTRODUCTION

secondary data was obtained from the UCU activated wastewater treatment plant office to help compare the parameter quality of the effluent. This information contained data collected on several parameters to determine the compliance of the plant to the National Standards for Wastewater effluent discharge into the environment from 2014 to 2023. three parameters (BOD_5, E. Coli, and pH) in the secondary data are considered in this study and not all months of the years in that period are accounted.

Effluent samples were collected at two different times: afternoon (2pm), and evening (4pm). The key parameters tested were pH, turbidity, color, E. coli, total coliform, and BOD_5. The findings were guided by the Singapore's Public Utilities Board's Technical Guide for Greywater Recycling (PUB, 2014), which was selected because it gives the non-potable water quality requirements for toilet and urinal flushing.

4.1.0 Physicochemical and Bacteriological Characteristics of Raw Effluent from The Ucu Wastewater Treatment Plant.

The parameters of interest are turbidity, pH, color, E. coli, total coliforms, and BOD_5. These parameters will be monitored before treatment, after treatment and during distribution of the effluent.

The standards and guidelines considered for this study are the National Environment Standards-for Discharge of Effluent into Water or Land and the Singapore Public Utilities Board (PUB) guidelines. They are contrasted with the obtained lab results as follows.

TURBIDITY

Turbidity is the measure of the cloudiness or haziness of the effluent caused by the presence of suspended particles like silt, clay, and organic matter. It is measured in Nephelometric Turbidity units (NTU).

Secondary data obtained from the activated AWWTP did not provide information regarding the turbidity of the effluent.

the turbidity value was found to be 18.2 NTU In the afternoon and was 34.9 NTU. the evening value This result is typical of secondary effluent which has not gone through tertiary treatment like filtration. The effluent turbidity values do not comply with the Singapore PUB guidelines, (<2 NTU). This might be an indication of an upset or hydraulic surge in the wastewater treatment process.

For the atmospheric conditions, there was a rain storm before the evening sample was collected which might have resulted in disturbance of the wastewater in the wastewater treatment plant, resulting raising of any settled particles in the de-sludging chamber. This therefore explains why the evening turbidity value is higher that the afternoon value.

The turbidity results support the necessity for filtration, specifically sand filtration given the high levels of turbidity. Reducing the turbidity of the effluent will prevent suspended particles from shielding pathogens from applied disinfectants such as chlorine.

TOTAL COLIFORMS (TC)

Total coliforms are group of bacteria indicating the general microbiological quality of water, rod shaped organism found widely in the environment (soil, plants) intestinal tracts of warm-blooded animals.

The total coliform counts recorded 276CFU/100ml in the afternoon and 95CFU/100ml in the evening showing the lower count in the evening than to the afternoon may be attributed to the dilution effect of rainfall.

BIOCHEMICAL OXYGEN DEMAND BOD5

Represent the amount of oxygen dissolved by aerobic microorganisms to break down organic matter in a sample water over a period of five days. the BOD5 value for afternoon and evening where within the limit according to Singapore PUB limit of <5mg/L meeting the environmental standards for effluent discharge and compliance with UCU wastewater treatment plant in removing soluble organic pollutants.

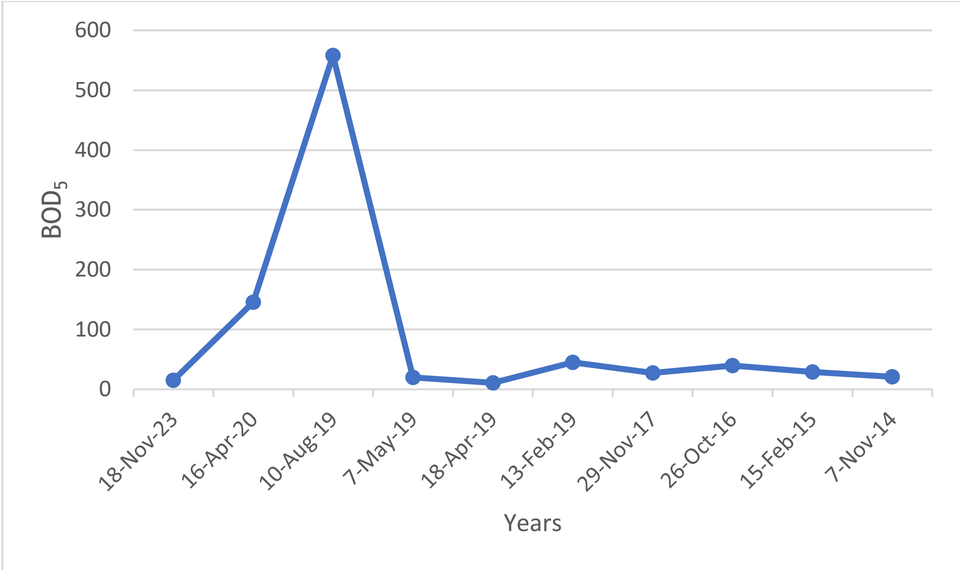


Figure 5: trend over seven-year period

BOD_5 concentration shows the extents of organic pollution in water. BOD_5 levels in effluent sample indicate a presence of organic matter from wastewater this allows insight into how effective treatment system is removing organic particle.
treatment process, organic matter is reduced through the action of aeration where blowers are introduced into wastewater to provide air to promote aerobic microbial breakdown of the loaded organism in the effluent likely to originates from students' residence and quest quarters, DH and campus offices where organic discharged into toilets and food rests flushed into the system.

COLOR

The clarity of the water is determined by Color, any total suspended particles change the color of water is the water quality parameter which refers to the presence of dissolved or suspended substances that cause water to appear discolored.

the afternoon results were 8 PtCo in and 2.3 PtCo in the evening. These both complied with the PUB guidelines of <15 PtCo. A low color indicates a low concentration of organic compounds that may make water or effluent dirty and unappealing observation affecting public acceptance.

ESCHERICHIA. COLI (E. Coli)

E. coli is indicator used to assess the microbiological quality of wastewater effluent, its presence fecal contamination. According to PUB guidelines, treated wastewater must be zero E. coli in a 100ml sample (PUB, 2014). These stringent standards exist because, although E. coli its self is generally not pathogenic, serves as dependable indicator of the possible harmful fecal origin of pathogens like salmonella therefore detecting E. coli sign of treatment process has not fully eliminate fecal contamination.

Microbial count from effluent show that contamination from human waste while E. coli colony counts are lower than those in raw sewage indicating that some pathogens are removal during treatment, they are capable of exceeding the limits. The afternoon sample recorded 385 CFU/100ml, evening 334 CFU/100ml both are not meeting guideline

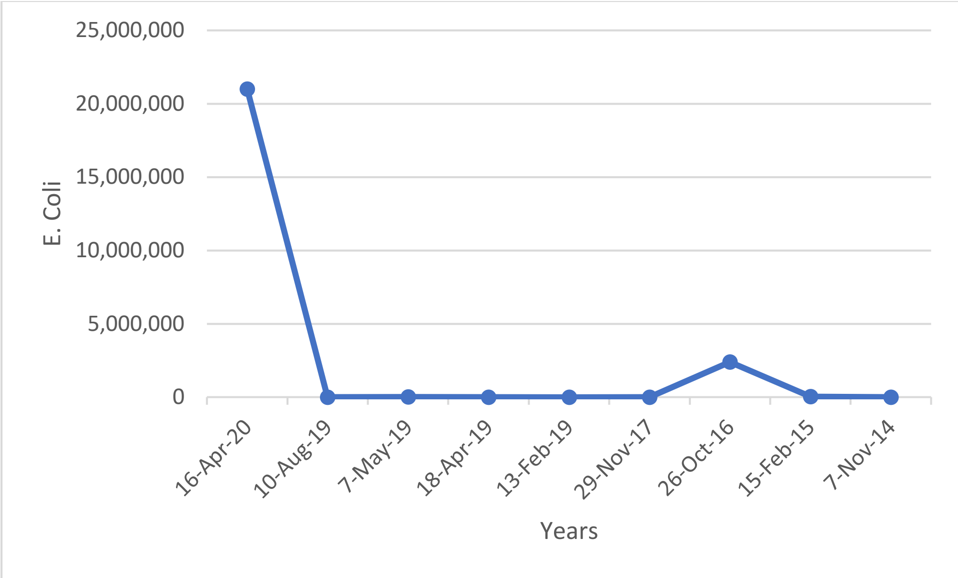


Figure 6: E. Coli trend over seven-year period

In the secondary data, the E. Coli levels were significantly higher on 16th April, 2020. In this period, the world was struck by the COVID-19 virus. The President of the Republic of Uganda initiated a lockdown in the country from 30th March to 30th June (Katana *et al.*, 2024). The very high level of E. coli detected in the effluent on 16th April, 2020 could be a result of the scaling down of the wastewater treatment plant operations because the operators were either at home or had limited access to the premises.

pH VALUE

pH measures the acidity or alkalinity of the effluent by indicating the concentrations of hydrogen ions. the pH scale ranges from 0-14, with 7 representing neutral value, values below 7indicate acidity while above 7 indicate alkalinity.

The measured effluent pH value of 9.1 in the afternoon and 9.2 in the evening fall outside the Singapore PUB guideline range of 0.6-0.9. to adjust the effluent to the required range, dosing with sulfuric acid is necessary to slightly reduce pH. pH levels are likely to be influenced by alkaline cleaning products used in residence halls and staff houses and detergents as well as food waste from kitchens.

Secondary data indicates that over the past seven years, the effluent pH has generally remained within the acceptable limits set by the Singapore PUB for non-potable water used in toilets flushing. (6.0-9.0)

From 18`th/November 2023 -15`th February 2025 effluent PH consistently remained within the range of 6-8. Data shows that the effluents the effluent was more acidic which may have resulted from the use of acidic cleaning products and disinfectants in campus toilets and bathrooms such as hydrochloric acid (HCL) the recent primary data shows that the effluent is slight alkaline suggesting increased use of alkaline compounds like sodium carbonate which elevate the pH

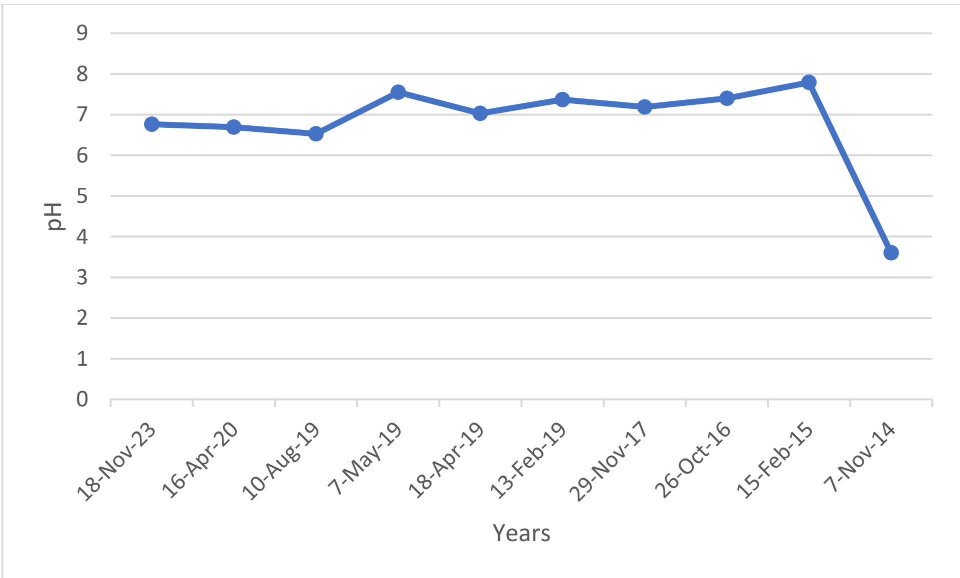


Figure 7: pH trend over seven-year period

4.1 Influent discharge.

The wastewater treatment plant receives both grey and block from halls of residents, office and staff quarter and discharges all the liquid to the screening point as the past treatment process then later to equalization chamber and sedimentation take

Table 3: Shows Time taken to fill a 19L bucket of influent

S/No	Volume (m^3)	Time (s)
1	19	14.20
2	19	15.30
3	19	15.31

Average time t to fill a 15L bucket.

$t = (14.20 + 15.30 + 15.31) / 3$

$t = 15.27s$

influent discharge = volume of fluid / time (Munson, Young and Okiishi, 2019)

Volume of effluent = 19 L

Volume to SI units = 19/1000

= $0.019m^3$

influent discharge = $0.019m^3/15.27s = 0.0012m^3/s$

Effluent discharge, the effluent from the waste water treatment after convectional treatment is done is discharge to the environment through drain pipe of 110mm, for this purpose, the effluent need to retreated for non-potable use that toilet and urinal flushing (Putera ZXee, 2024).

: Shows Time taken to fill a 19L bucket of effluent

S/No	Volume (m^3)	Time (s)
1	19	8.23
2	19	8.24
3	19	8.27

Average time t to fill a 19L bucket.

$t = (8.23 + 8.24 + 8.27) / 3$

$t = 8.25$ s

Effluent discharge = volume of / time (Munson, Young and Okiishi, 2019)

Volume of effluent = 19 L

$1m^3$=100l

Volume to SI units = 19 / 1000

Volume = $0.019m^3$

Effluent discharge = $0.019m^3$/ 8.25 s

= $0.0023m^3$/s

4.1.1 Effluent treatment.

According to parameter tested, most of the parameters did not meet the guideline standards, turbidity, color, total suspended solids PH, total collide forms and E-coli. The suggested treatment process would be slow sand treatment think the rationale of the above can fall within the treatment mechanism incorporated with the plain sedimentation to allow for pretreatment and sludge settlement before discharging to the filters that may clog with the short time.

Required parameters for the treatment process are flow rate of the effluent (Qm^3/day) per day, surface area (A m^2), filtration rate/day, filtration velocity, sand depth, filter bed volume sand porosity, contact time and pore volume.

Designing a wastewater treatment system.

Depth filtration: will involve the physical removal of suspended particles from the secondary effluent passed through a granular filter media.

Mechanisms: straining, sedimentation, interception, adhesion, and flocculation.

Effectiveness of depth filtration.

Filter effluent turbidity, NTU = 0.5 NTU + 0.2 (filter influent turbidity, NTU) (Metcalf & Eddy Inc. et al., 2014).

Effluent particle typical size: 51.01μm (using microscopic image analysis)

Filter medium characteristics: 0.45mm (Metcalf et al., 2013)

Filter Influent flowrate (0.0023 m^3/s)

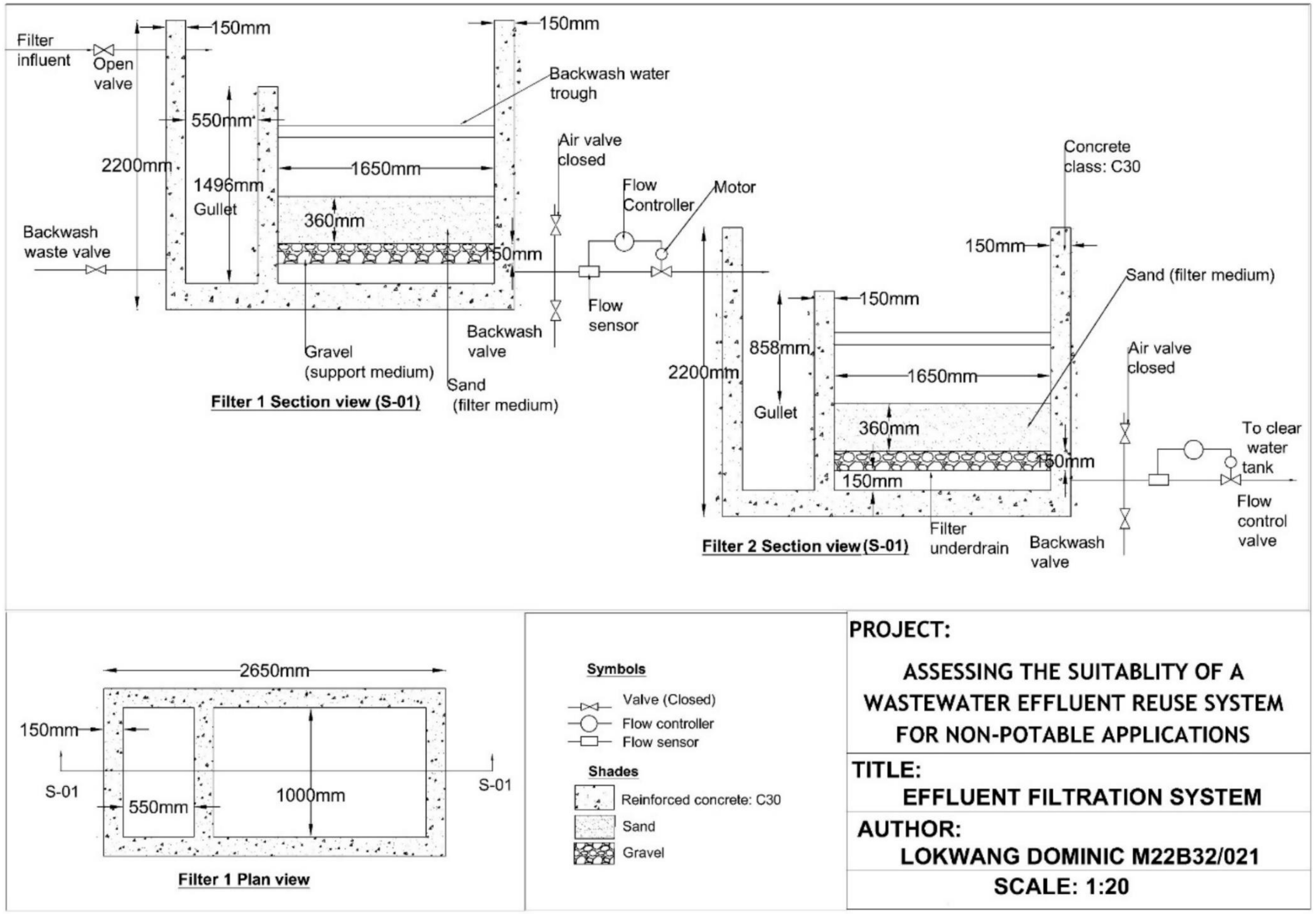
Filtration rate: 2.5m^3/m^2hr

The sand filter operation the filtration rate is relatively low (0.1and 0.3m^3/hr.), for the filtration rate of 2.4 m^3/m^2.day which is moderate with the contact time of

3.5hr which is ideal for biological activity and particles removal the area of 82.8m^2 and discharge of 8.28m^3/hr. is under sand filtration.

(ministry of water and environment water supply design manual second edition)

Determine the volume/quantity of effluent to supply the sanitary applianc


Filter influent
Open valve
150mm
150mm
Backwash water trough
550mm
2200mm
1496mm
Gullet
1650mm
Air valve closed
Flow Controller
Motor
360mm
Backwash waste valve
150mm
Flow sensor
Backwash valve
Gravel (support medium)
Sand (filter medium)
Filter 1 Section view (S-01)
Concrete class: C30
150mm
Sand (filter medium)
150mm
858mm
2200mm
Gullet
1650mm
Air valve closed
360mm
150mm
150mm
To clear water tank
Flow control valve
Filter underdrain
Backwash valve
Filter 2 Section view (S-01)
2650mm
150mm
S-01
550mm
1000mm
S-01
Filter 1 Plan view
Symbols
Valve (Closed)
Flow controller
Flow sensor
Shades
Reinforced concrete: C30
Sand
Gravel
PROJECT:
ASSESSING THE SUITABLITY OF A WASTEWATER EFFLUENT REUSE SYSTEM FOR NON-POTABLE APPLICATIONS
TITLE:
EFFLUENT FILTRATION SYSTEM
AUTHOR:
LOKWANG DOMINIC M22B32/021
SCALE: 1:20

4.1.2 **WATER DEMAND**

supply of treated effluent will as per the number of appliances to be supplied that is the number of flushing toilet and urinal in respect to the users, that is students and staff whose sanitary appliances are connected to existing wastewater treatment of UCU.

effluent from the UCU wastewater treatment plant is used as treated pilot- scale horizontal subsurface constructed wetland. Once the quality of the effluent meets the target parameters for non- potable reuse, a dual-pipe water system will be installed to supply the recycled water for flushing toilets, urinals and for irrigation. (Mosher, 2015).

According to Mosher (2015) design requirements, a separate reclaimed water distribution network should be developed to avoided cross contamination between potable water and non-potable water. The reused water will be conveyed from the clean water tank through outlet into a dedicated storage tank sized to hold a volume equivalent to at least 1.5 days of flushing demand. (Saudi Organisation for Standardization, Metrology and Quality, 2013).

As recommended in the Handbook on Feasibility studies for water reuse system, backflow prevention devices and labelling at all outlets points will be part of the reuse system. A monitoring plan should encourage so that the treated water is in line with non- potable reuse standards taking a priority on parameters such as BOD, TSS coliforms, and turbidity. Continuous application of chlorine in the system to allow for periodic chlorination of the treated effluent to facilitate safe microbial quality during storage and transportation (New Zealand Water and Wastewater Association, 2002).

This approach enables safe and reliable supply of water to be reused for sanitary flushing while preventing risks of cross connection with the potable water system.

Table 4: showing calculation table

Calculations	Calculated Parameters	Parameters checks
Discharge (m^3/s) =volume(m^3) /time(s) Q=V/T influent discharge = $0.019m^3/15.27s = 0.0012m^3/s$ Volume of effluent = 19 L Time = 8.25 seconds Discharge (m^3/s) =volume(m^3) /time(s) Q=V/T **Effluent discharge** $1m^3$=100l = $0.019m^3$ / 8.25 s	influent discharge =$0.0012m^3/s$ Effluent discharge =$0.0023m^3/s$	

Calculations	Calculated Parameters	Parameters checks
$=0.0023m^3/s$		
Maximum Day Demand (MDD) (90% of monthly amount) =demand/30(90/100) =7000/30(90/100) MDD = 210 m^3/day	MDD= 210m^3/day	
Storage (tank) 30% the MDD = 30/100*MDD (m^3/day =0.3*210 capacity=63m^3	50m^3/day (ok)	
P(Kw)= pgQH/3600η =1000kg/m^3 g(m/s^2) =9.8m/s^2	Power=3KW Number of Pannel=8pannels	

Calculations	Calculated Parameters	Parameters checks
Q (m^3/day) =198.72m^3/day H(m) =70m P=1000kg/m^3*9.8m/s^2*198.72m^3/day *70m/3600*0.3 P=1947456/3600*0.3 P=1803.2kWh Number of solar Pannel= Daily power required/peak power rating*5 Number of solar Pannel=1803.2kWh/50*5 Number of solar Pannel=7.2128=8pannels		
Battery size=required energy(W)/12*0.5 BS=3000/12*0.5 BS=500wh 160W) Voltage of 12v and lead acid battery Solar panel size=BS/hours of	BS=600Wh, panel=160W Charger controller=14A	

Calculations	Calculated Parameters	Parameters checks
sunshine Solar panel size=600/5 Solar panel size=120W =120+(30/100*120) =156=160 (Get a panel of 160W) Charger controller=160/12=13.33=14A		

Table 5:showing the cost benefit analysis.

#	parameter	%	value
	Capital expenditure (CAPEX)		160373552.5
	Annual operation and maintenance (O&M)	8% of capital expenditure	12827004.2
	Unit water price (NWSC institutional tariff)	4358	
	Project lifetime	10 years (Assumed)	
	Discount rate	11% (Assumed)	
	Daily effluent reuse	50m^3/day	

	Annual volume=Daily*365	50*365	18250
	Annual benefit (Avoided water cost) =Volume annual *unit price	18250*4358	79533500
	Net annual benefit= Annual benefit-O&M	79,533,500-12,827,004.2	66,706,495.8
	Payback period=initial investment/annual cash inflow	160373552.5/66,706,495.8	2years,4months ,24days.

	NPV=TPV-initial investment	NPV=394,135,330.4-160,373,552.5	NPV= Ugx 233,761,777.9
	Pi=TPV/initial investment	394,135,330.4/160373552	Pi=2.5

4.1.4 Power required for pumping treated water

Technical specification is described as pump speed of 2902 rpm calculated flow of 8.522m^3/hr. resulting to the head of 74.15m, the maximum head of 81.7m can also be pumped. it has 8 stages and 8 impellers. The installation process requires outside temperature (ambient) of 60•c and pressure of 16bars. connection of oval/RP to the inlet is 2 inch and outlet is 2inch the pressure rating for connection is PN16 and to the flange size for the motor FT130. The rated power is determined to be 3KW with the frequency of 50Hz giving the voltage of 3*220-230D/380-400Y and the current of 10.6/6.10A but the starting current is 1130-1140% with power factor of 0.86-0.84. however, the profile load for the designed power selection is show below

item	Calculated Parameters	checked
Power 1	2.871kw	
Power 2	2.563 kw	
Pump Efficiency	67%	
head	74.15	
flow	8.522m^3/hr.	
Energy consumption	3196KWhr/year	

4.1.5 Transmission

A transmission line is the main pipe that convey treated water from either borehole or clean water tank to elevated storage distribution tank. Designing of pipeline is very important ensuring that adequate flow, stable pressure and minimal losses throughout the network. (Alemayehu et al., 2020)

Transmission lines compose of large diameter pipes design to maximize hydraulic and structural duality across long distance. design need evaluation factors of topography, projected water demand, choices of pipe material and cost effectiveness (Mays, 2019). performance of transmission is assessed using modeling software Grundfos used for simulation of flow distribution, pressure variation and energy consumption within the network (Rossman, 2000).

The data was collected using Handy GPS, hand book and pen, elevation differences were determined from the clean water tank to the elevated tank is (1276.51-1217.27) m 59.24m

70m in which the elevated tanked will be placed. The discharged of effluent was determined to be 0.0023m^3/online software called Grundfos was used for determining the power that will pump the water through the transmission to the elevated tank and later distribute the water to the appliances by gravity.

The source of water supply is from the UCU wastewater treatment plant effluent that will be treated to supply water from the design clean water tank or contact time tank which lies with 470959.276 Eastings,38852.802 Northings and Altitudes 1217.27m above mean seal level. The total length to the reservoir is 437m along the Anykira small gate from the source to the reservoir.

	Eastings (m)	Northings (m)	Altitude (m)	Length (m)	remarks
1	471280.993	39037.346	1276.51	0	Reservoir
2	471240.667	38890.804	1259.12	153	School of Business Road
3	471146	38882	1243	95	End road to Anykira gate
5	470959.276	38852.802	1217.27	189	Source (WWP)
				437	

OPTIMUM POWER

Upper graph – shows the pump head efficiency, and operating the blue cure represent the pump`s head (H) as a function of flow rate (m^3/h) a horizontal red line shows the required head of 70 m.

Intersection point with yellow/orange circles shows the actual operating point of the pump, flow rate 8.595m3/h and head 70 m.

The right-hand vertical axis shows the pump efficiency (%) the two block curves below the head curve represent pump efficiency which is combined pump +motor efficiency at the operating point which are pump efficiency =69.8% and overall efficiency (pump +motor) =52.4%.

The lower graph- that is pump power input, the lower blue curves show that is P1(shaft or brake power), p2(input electrical power) power increases gradually with flow at the selected operating point (p1=3.121Kw, p2=2.344kW)

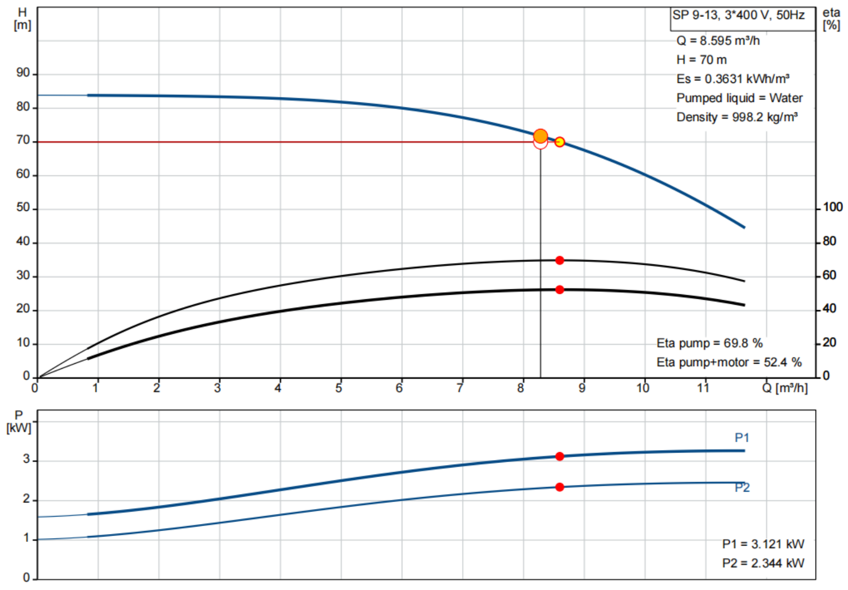
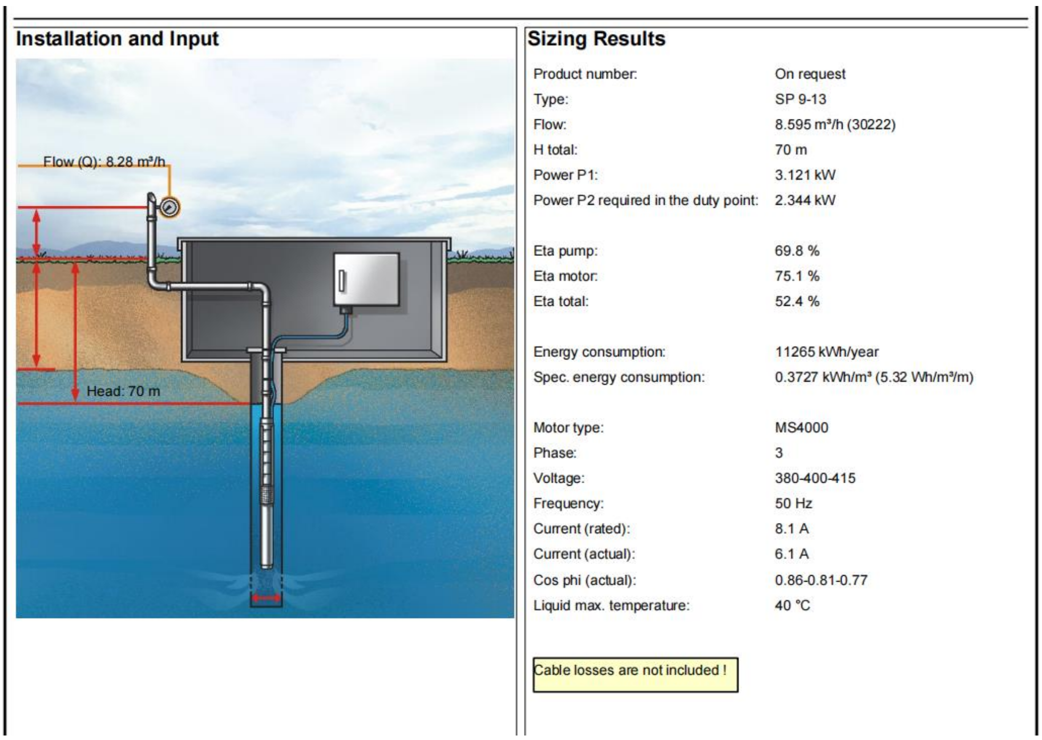
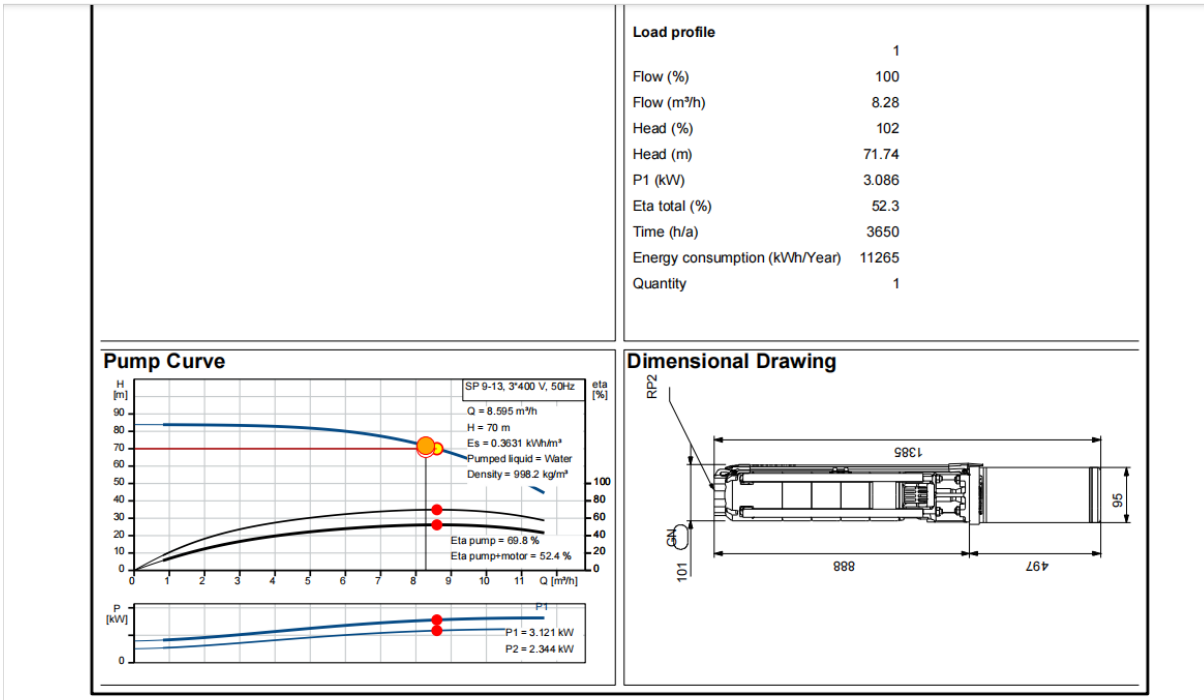


Figure10:*showing optimum power curve of head and discharged*



Product number:	On request
Type:	SP 9-13
Flow:	8.595 m³/h (30222)
H total:	70 m
Power P1:	3.121 kW
Power P2 required in the duty point:	2.344 kW
Eta pump:	69.8 %
Eta motor:	75.1 %
Eta total:	52.4 %
Energy consumption:	11265 kWh/year
Spec. energy consumption:	0.3727 kWh/m³ (5.32 Wh/m³/m)
Motor type:	MS4000
Phase:	3
Voltage:	380-400-415
Frequency:	50 Hz
Current (rated):	8.1 A
Current (actual):	6.1 A
Cos phi (actual):	0.86-0.81-0.77
Liquid max. temperature:	40 °C

Cable losses are not included !



Load profile	1
Flow (%)	100
Flow (m³/h)	8.28
Head (%)	102
Head (m)	71.74
P1 (kW)	3.086
Eta total (%)	52.3
Time (h/a)	3650
Energy consumption (kWh/Year)	11265
Quantity	1

Figure 8: show load profile

Distribution network

The distribution of water is by gravity through which elevated tank/reservoir, highest point is known to determine the pressure that equalizes the system, using Epanet to simulate the system using Hazen William formular. The pressure differences will be known, diameter and the lengths of the pipes will equally be determined using the formular (Hazen William).

Dataset of elevation point were picked using Handy GPS such that the highest point within the distribution line must not be higher than that of elevated tank for pressure operation.

The layout of a water supply system illustrates both the physical arrangement and hydraulic features of the network, detailing how water is transported from the source, to the appliances through the elements of reservoir, pipes, and fittings. Hydraulic and water quality were performed using EPANET, a widely modelling software, to evaluate flow distribution, pressure variation and overall operational performance of the system (Rossman, 2000).

This layout offers a clear visual depiction of network connectivity, showing pipe sizes, nodes elevations. It is an essential tool for detecting potential hydraulic challenges, like low pressure, excessive velocities, or areas with inadequate supply. It facilitates performance assessment under varying demand conditions. Supporting effective planning, design optimization and potential future expansions of the water distribution network.

Table 6: *showing Dataset for the distribution line. (coordinates)*

Location	Easting(m)	Northing (m)	$L=\sqrt{((E_2-E_1)^2+(N2-N_1)^2)}$ (m)	Elevation (m)
Source WWP	470959	38852	0	1217.27
WWP Gate	470988	38870	34	1230
Opposite eng Faculty	471044	38870	56	1231
Opposite Foot Path	471097	38876	54	1236
End Road	471146	38882	50	1243
Ben Bella Studios	471178	38865	37	1254
Ben Bella	471213	38885	41	1261

Location	Easting(m)	Northing (m)	$L=\sqrt{(E_2-E_1)^2+(N2-N_1)^2}$ (m)	Elevation (m)
Incinerator	471241	38923	48	1264
Next to school of business road	471240	38890	33	1259
Reservoir/tank	471280	39037	152	1276
Total length			**443**	
From Ankira small gate to Archives				
End road	471146	38882	0	1243
Opposite Nsibambi	471137	38931	50	1245
Opposite Green House	471136	38980	49	1241
Opposite Sabiti	471140	39028	49	1246
Opposite DH	471142	39075	47	1246
Opposite	471150	39124	50	1242

Location	Easting(m)	Northing (m)	$L=\sqrt{((E_2-E_1)^2+(N2-N_1)^2)}$ (m)	Elevation (m)
Firewood				
Opposite Guild	471158	39173	50	1243
Opposite Library	471175	39218	49	1244
Opposite Library	471196	39264	51	1243
Opposite N block	471213	39309	49	1247
Opposite Comp Lab	471227	39354	48	1248
Near Allan	471246	39398	47	1252
Opposite. Archives	471298	39410	54	1257
Total length			**441**	
Through Bishop tucker to old pitch				
Opposite. Bishop Tucker	471296	39459	0	1248

Location	Easting(m)	Northing (m)	$L=\sqrt{(E_2-E_1)^2+(N2-N_1)^2}$ (m)	Elevation (m)
Near Bishop Tucker	471279	39439	27	1239
Opposite. Bishop tucker Entrance	471274	39536	98	1237
Opposite George	471232	39564	51	1235
Opp. Old pitch	471189	39593	52	1229
Gate(W)	471161	39613	35	1226
Total length			263	
Along Canteen area				
Opposite. Nkoyoyo parking	471173	39543	0	1231
Opposite Law faculty	471147	39501	50	1228
Opposite	471104	39474	51	1229

Location	Easting(m)	Northing (m)	$L=\sqrt{((E_2-E_1)^2+(N2-N_1)^2)}$ (m)	Elevation (m)
Save the mothers				
Opp. Canteen toilet	471085	39428	50	1227
Opposite ICMI	471073	39380	50	1233
Lib Rise	471060	39329	53	1230
Opposite main gate	471044	39279	53	1231
Opposite Basket court	471027	39223	59	1230
Opposite Sport toilet	471017	39180	45	1233
Opposite power station	471065	39159	53	1239
Total length			**419**	
Road to Engineering faculty				

Location	Easting(m)	Northing (m)	$L=\sqrt{((E_2-E_1)^2+(N2-N_1)^2)}$ (m)	Elevation (m)
Opposite DH	471065	39113	0	1235
Beginning of sabiti	471051	39059	56	1236
end of sabiti	471044	39008	53	1236
Opp. Nsibambi	471073	38956	60	1234
Opp. Wash Bay	471073	38907	49	1233
Opp. Faculty	471042	38872	47	1233
Total length			265	
To faculty of Agriculture				
Opp. WWP	470993	38859	0	1226
Tech gate	470948	38849	47	1225
Carpentry	470936	38800	51	1224
Faculty agricultural sciences	470932	38750	51	1223
Total length			149	

Location	Easting(m)	Northing (m)	$L=\sqrt{(E_2-E_1)^2+(N2-N_1)^2}$ (m)	Elevation (m)
Along library rise opposite computing Library	471150	39315	0	1234
End of the road between library and N block	471198	39270	150	1247
Total length			**150**	
Road from Computer lab (N block) to canteen area				
Computer lab	471227	39354	0	1248
Near K block	471183	39382	53	1237
Opp Academic`s offices	471081	39407	105	1228
			158	

Source: Handy GPS

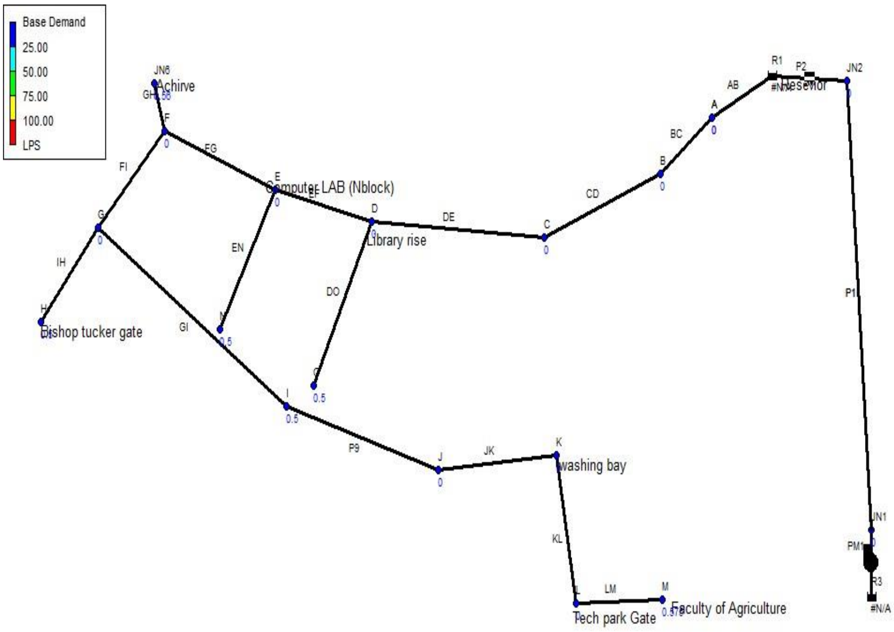


Figure 9:showing the Distribution network (EPANET 2.2)

Table 7: showing nodes variations

Node ID	Elevation (m)	Base demand (Lps)	Demand (Lps)	Head (m)	Pressure (m)
Node B	1259	0	0	1278.68	19.68
Node A	1279	0	0	1278.84	-0.16
Node C	1256	0	0	1278.23	22.23
Node D	1248	0	0	1277.04	29.04
Node F	1252	0	0	1275.95	23.95
Node JN6	1257	0.56	0.56	1275.9	18.9
Node H	1228	0.5	0.5	1275.66	47.66
Node I	1227	0.5	0.5	1275.64	48.64

Node ID	Elevation (m)	Base demand (Lps)	Demand (Lps)	Head (m)	Pressure (m)
Node J	1226	0	0	1275.57	49.57
Node K	1239	0	0	1275.42	36.42
Node L	1225	0	0	1275.07	50.07
Node M	1223	0.575	0.57	1274.73	51.73
Node N	1226	0.5	0.5	1276	50
Node O	1255	0.5	0.5	1276.86	21.86
Node G	1229	0	0	1275.72	46.72
Node E	1247	0	0	1276.17	29.17
R1	1279	#N/A	-3.13	1279	0

Table 8:showing Links variations

Link ID	Length (m)	Diameter (mm)	Velocity (m/s)	Unit head loss (m/km)
Pipe BC	131	125	0.26	1.22
Pipe CD	198	110	0.33	2.27
Pipe DE	198	90	0.49	6.04
Pipe GH	75	75	0.13	0.61

Link ID	Length (m)	Diameter (mm)	Velocity (m/s)	Unit head loss (m/km)
Pipe FI	131	90	0.25	1.69
Pipe IH	131	75	0.11	0.49
Pipe GI	104	90	0.17	0.83
Pipe P9	105	75	0.13	0.63
Pipe JK	104	63	0.18	1.48
Pipe KL	75	50	0.29	4.57
Pipe LM	75	50	0.29	4.57
Pipe EF	198	90	0.41	4.38
Pipe FG	75	90	0.34	2.96
Pipe EN	150	63	0.16	1.15
Pipe DO	150	63	0.16	1.14
Pipe AB	131	125	0.26	1.22
	2031			

pressure distribution across the various nodes within the network was simulated in EPANET. the x-axis represents the pressure at each node (meters of head) and the y- axis shows the percentage of nodes with pressure less than or equal to the specific value. indicating that nodes experience moderate to high pressure levels, typically ranging from 20 -50 meters, with the majority concentrated around 45-52m. a few nodes record pressure below 20m, likely corresponding to areas of higher elevation or greater distance from the main supply source. The smooth upward trend of the curve demonstrates generally balanced pressure distribution across the network ensuring sufficient service levels for consumers. Nevertheless, higher-pressure nodes need regulation to prevent excessive pressure and potential pipe damage in low lay areas (EPA,2020, Ministry of water of water and environment, 2021).

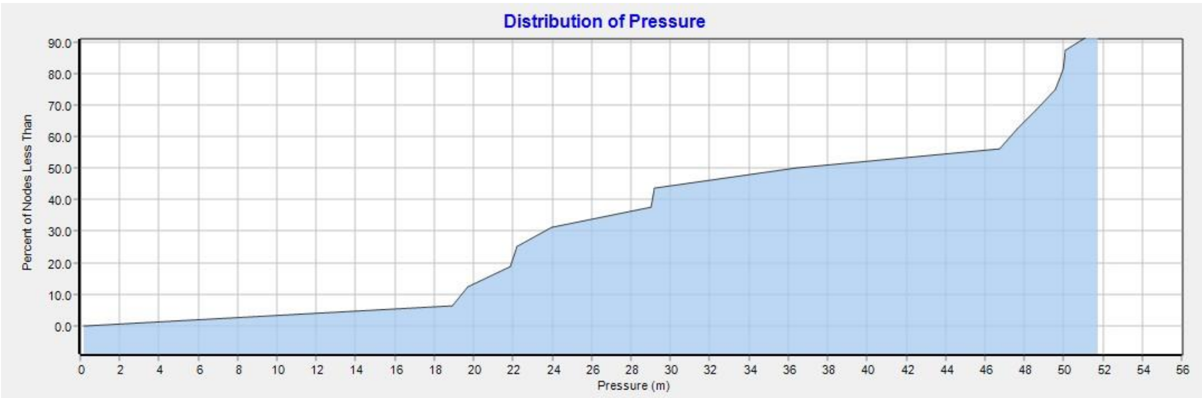


Figure 10:showing pressure distribution

The distribution of water demand also various with nodes within the network of water supply. The x- axis represents the demand at each node (LPS) and the y- indicates the percentage of nodes with demand less than or equal the specific value. Moderate demand levels generally between 0.10 and 0.50 LPS only a few nodes record higher demand approaching 0.58 LPS. The trend of the graph reflects a fairly uniform distribution of water demand across the service area, showing that the network design provides a well-balanced supply among the consumption points

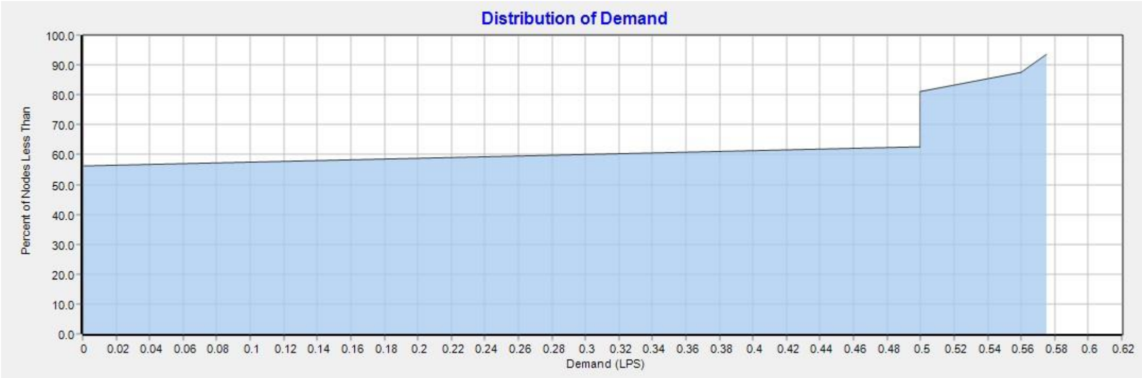


Figure 11:showing the graph of demand distribution.

The graph presents the elevation profile of the water supply system generated from Epanet hydraulic analysis each plotted point represents the variation of induvial nodes along the pipe line. The variations depict the topographical features of the project area which affect the hydraulic head and pressure distribution within the network. The graph shows that the elevation differences from the reservoir to the consumers showing that it is fed gravity. (EPANET 2.2 user manual)

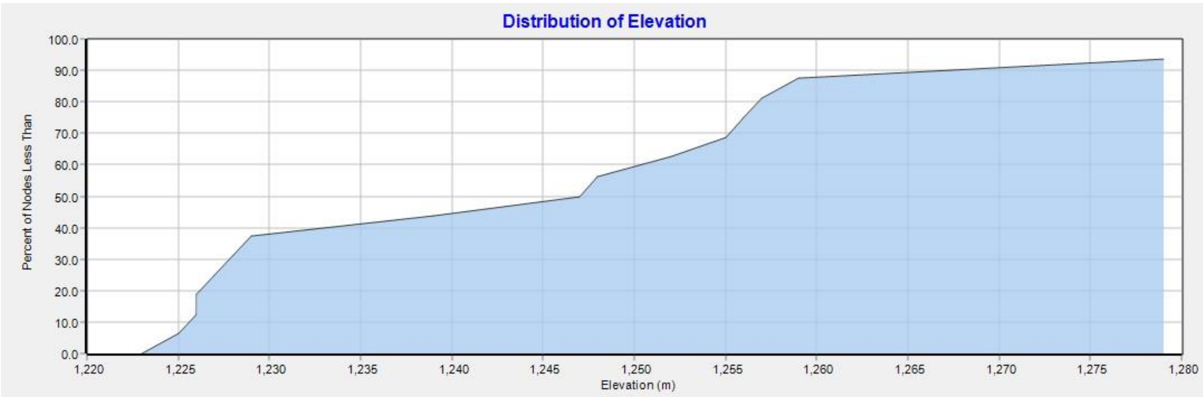


Figure 12: showing elevation differences

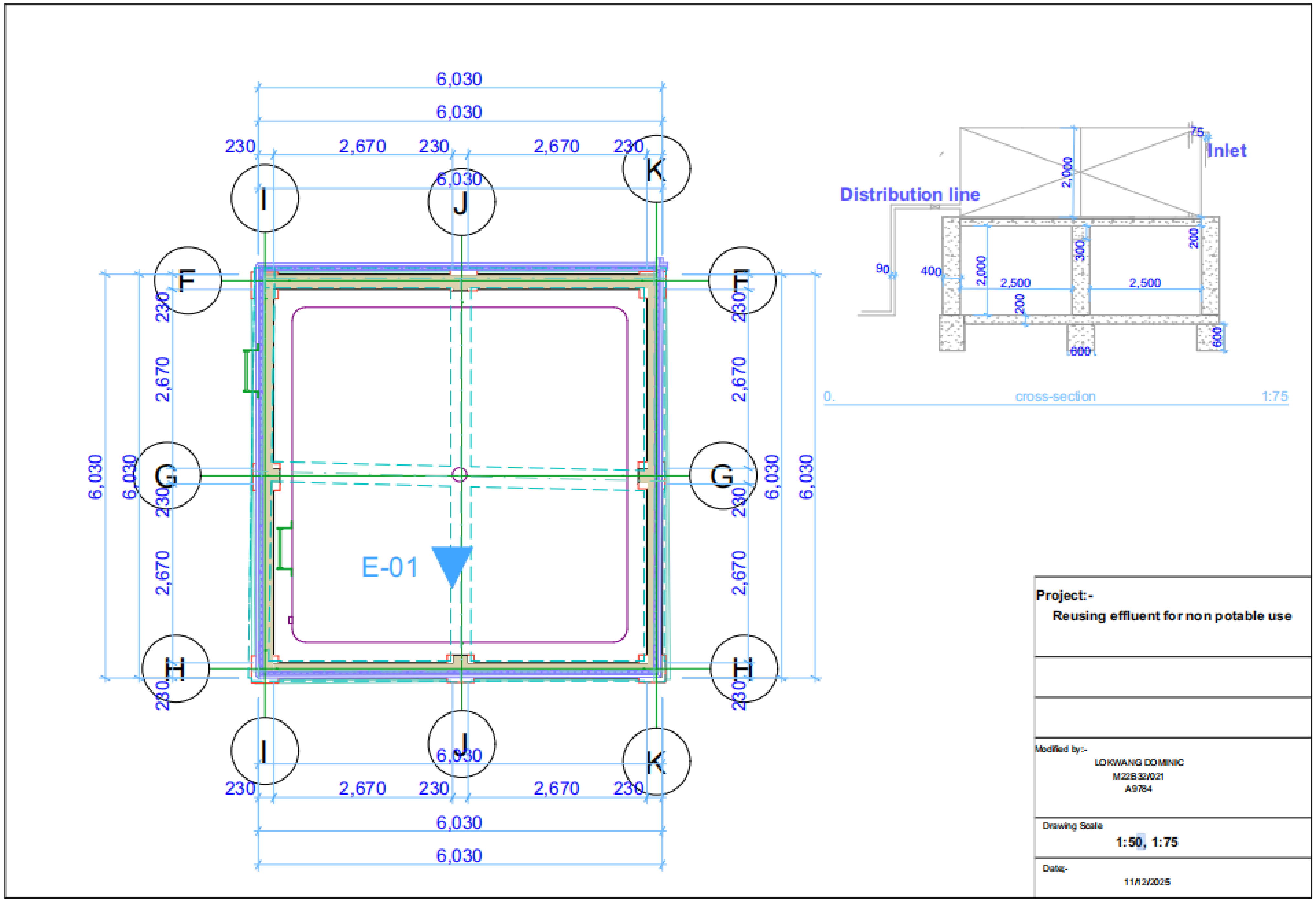
4.1.7 Water tank

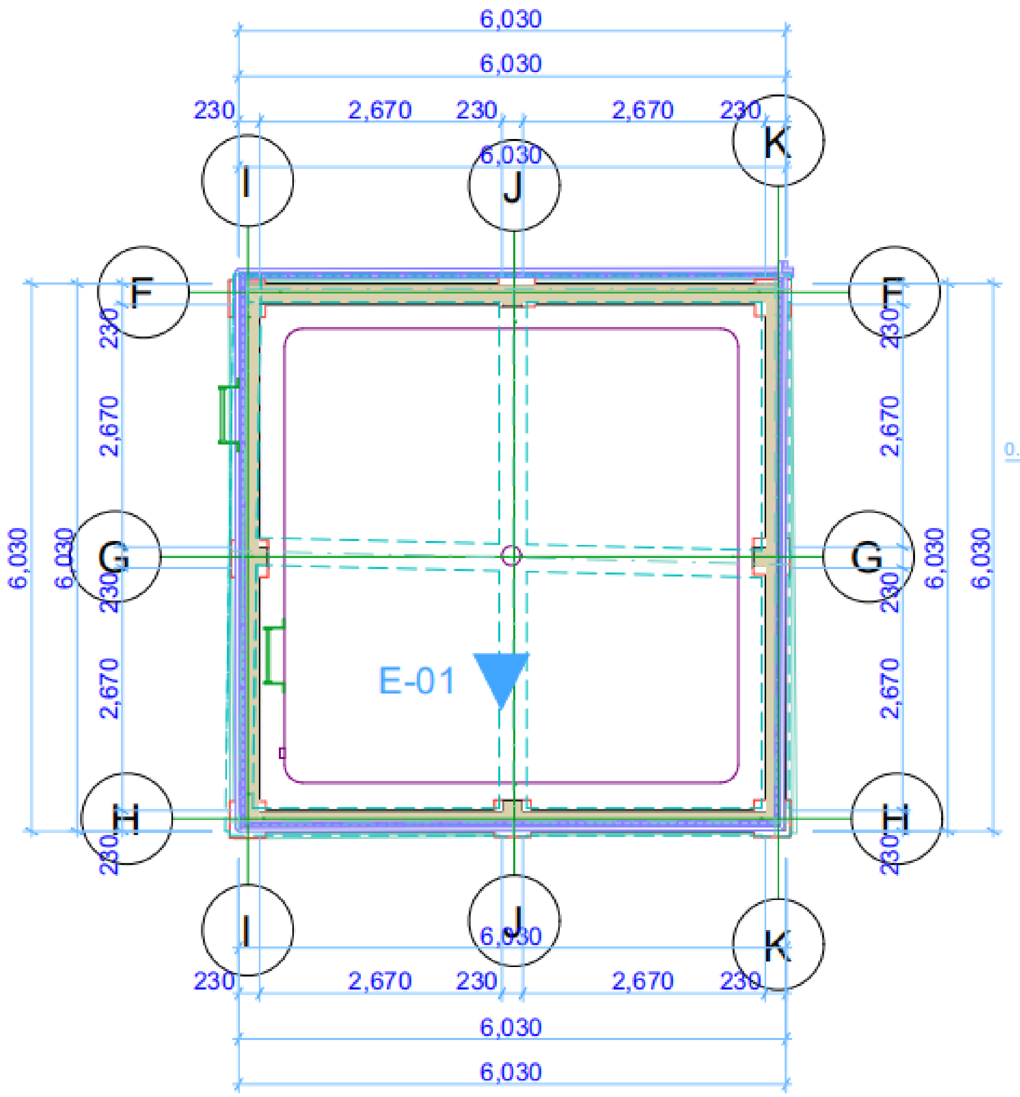
Reliable water storage systems are vital for maintaining a steady and dependable water supply to institution and distribution networks. Elevated water tank is particular important in achieving this as it provides adequate storage capacity, regulate distribution pressure and supply water during period of demand during temporary shortage.

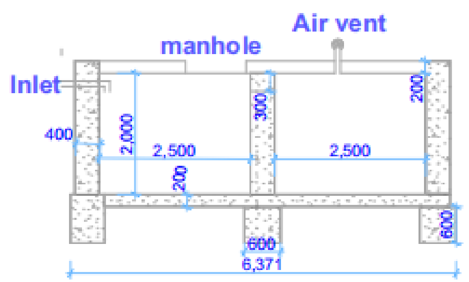
Structural arrangement and functional element of a $50m^3$/day of steel tank intended to store treated water and deliver into the distribution line,

Configuration measuring 6.03m x6.03m, with clear storage space of 5.0m x5.0m, the structure is supported by reinforce concrete columns and footings and incorporated based footing.

The accompanying plan and cross-sectional drawing illiterates the tank geometry including the element thickness, inlet and outlet pipe’s location. Material requirements, service features and overall design layout of the elevated tank as depicted in the drawings.


6,030
2,670
230
E-01
Distribution line
Inlet
2,000
2,500
300
200
400
90
600
75
cross-section
1:75
Project:-
Reusing effluent for non potable use
Modified by:-
LOKWANG DOMINIC
M22B32/021
A9784
Drawing Scale
1:50, 1:75
Date:-
11/12/2025





0. cross-section 1:75

Project:-
Reusing effluent for non potable use

Modified by:-
LOKWANG DOMINIC
M22B32/021
A9784

Drawing Scale
1:50, 1:75

Date:-
11/12/2025

4.1.8 Determining the cost benefit analysis.

The third element of this study is the cost benefit analysis (CBA) in determining the financial viability of reusing effluent for non-potable use within Uganda Christian university. The estimation of the cost will begin with identification of all the capital costs, materials for construction wetland (liner, gravel, outlet and inlet pipes and plant of the wetland), a storage tank for treated water, a min-pump for water for water transfer, and transmission and distribution of non-potable water to selected sanitary facilities. Operational and maintenance cost, such as energy for pumping, regular cleaning and minor maintenance, will be estimated based on the rates used in similar studies (Ou et al., 2006; Kadlec and Wallace, 2009). benefits will be quantified by calculating the volume of potable water saved through substitution with treated effluent for non-potable use. The water demand for sanitary use will be determined from population and per capita demand guidelines from water Supply Design M annual (Republic of Uganda, 2018). Using the current National Water and Sewerage Corporation (NWSC) tariffs, this volume will be translated into annual cost savings. Environmental benefits, such as reduced discharge of untreated effluent into environment, will be described qualitatively. Finally, the payback period and net benefits will be computed to determine whether the cost of implement the reusing system is justified by savings and environmental benefits (Kyambadde et al., 2004; WHO, 2006).

4.1.9 Concrete Mix Design

Batching by volume.

Concrete yield is the volume of freshly concrete different from a known quantity of ingredients. the volume of hardened concrete may be less than expected. Due to waste, spillage, over excavations, spreading forms entrained air/settlement of wet mixtures none of which are the responsibility of the producer.

It is therefore paramount to cater for the losses when producing concrete, when batching by volume note that the yield is the volume.

Volume of 1 bag of cement is 50kg as packed which is equal to 33liters

Yield of mix=2/3(loose of cement + sand +aggregate)

mix proportion by volume is 1:2:4 meaning 1 part of cement, 2 parts of sand and 4 parts of aggregate/stones and 1:3:6 where prescribed to use such mixes originated from UK and are suitable for well graded round aggregates.

The south Africa materials, proportions with equal volume of sand and stones (1:3:3 or 1:4:4) are more like to work. S.K, Suryakanta “How to estimate yield of concrete for volume batching”

Materials required.

Volume of concrete required (m^3) = LWH

Number of batches of mix=volume of concrete (L)/Yield of mixtures.

Sand trip = batches *(33*3)

Aggregate = batches *(33*3)

Table 9:Showing material acquisition

item	eleme nt	Volume(m^3) =LWH	volume 2/3(1*33:3*33:4*33)	Materials=v/y		
Filter media	slab	v=2.75*1.4*0.2 v=0.77m^3	0.176m^3	cement	sand	Ag g
				5	1	2
	slab	v=1.65*1.4*0.2 v=0.462m^3	0.176m^3	3	1	2
	wall	v=2.75*2*2.20.2 v=2.42 m^3	0.176m^3	14	2	3
	wall	v=1.49*1*0.2*2 v=0.596 m^3	0.176m^3	4	1	2
		v=1.4*2.2*0.2*4 v=2.46 m^3	0.176m^3	14	2	3
		v=1.65*2.2*2*0.2 v=1.452m^3	0.176m^3	9	1	2
Length of= (length/spacing +1) *length*sides						
		l= (1.75/0.15+1) *1.75*4				
		l=177.24m	(16*16/162) * 177.24m	280kg		
		l= (1.65/0.15+1) *1.65*4 l=158.4m	(16*16/162) * 158.4m 250.272kg	250.272kg		

		l= (1.4/0.15+1) 1.4*4 l=231.392m	(16*16/162) *231.392m 365.60kg	365.60kg		
		l= (1.49/0.15+1) *1.49*4 l=122.45m	(16*16/162) *122.45m =193.50kg	193.50kg		
		l= (2.2/0.15/0.15+1) *2.2*8 l=1103m	(16*16/162) *1103m 1743.012kg	1743.012kg		
		l= (1/0.15+1) *1*2*4 l=61.28m	(16*16/162) *61.28m =96.837kg	96.837kg		
		Total length=1731.312**m**	1731.312**m**	2735.9kg		
		BRC				
Area of the filter bed=LW A=4.4*1.4 A=5.5m^2						
Elevated tank	footin g	V= (0.6*0.6*0.6) *9 V=1.944m^3	Y=2/3(1*33+3*33+4*33) =0.176m^3	12	2	3
	colum n	V= (0.4*0.4*2) *9 V=2.88m^3	Y=2/3(1*33+3*33+4*33) =0.176m^3	17	2	3
	slab	6.03*6.03*0.2	Y=2/3(1*33+3*33+4*33)	42	5	6

		$=7.272m^3$	$=0.176m^3$			
	beam	V=6.03*0.3 V=3.256	Y=2/3(1*33+3*33+4*33) $=0.176m^3$	19	2	2
Clear water tank	footing	V= (0.6*0.6*0.6) $V=1.08m^3$	Y=2/3(1*33+3*33+4*33) $=0.176m^3$	7	1	1
	slab	V=6.03*6.03*0.2*2 V=7.2721*2 $V=14.544m^3$	Y=2/3(1*33+3*33+4*33) $=0.176m^3$	83	9	11
	column	V= (0.4*0.4*2) *9 $V=2.880m^3$	Y=2/3(1*33+3*33+4*33) $=0.176m^3$	17	2	3
	beam	V= (6.03*0.3*0.3) *2 $V=3.616m^3$		21	3	3
	Bars (slab wall)	Bars of steel (slab and the wall)	Weight of steel (kg) $=(D^2/162)$ *Length			
		l= (6.03/0.15+1) *2 l=52.26m	(16*16/162) *52.26 =82.584kg	82.584kg		
		(6.03/0.15+1) *4 l=321.6m	(16*16/162) * 321.6 =508.207kg	508.207kg		
		l=*(2/0.15+1) *2*4 l=114.667m	(16*16/162) *114.667	181.202kg		

Table 10:showing estimated cost of the materials

ITEM	UNIT	QTY	RATE	AMOUNT
UPC-pipe DN125 PN16	m	270	25316	6835500
UPVC-pipe DN110 mm PN 16	m	198	17800	3524400
HDPE pipe DN90 mm PN16	m	925	10500	9712500
HDPE pipe DN75 mm PN16	m	529	7500	3967500
HDPE pipeDN63 mm PN16	m	404	4900	1979600
HDPE pipe DN50 mm PN16	m	150	2800	420000
HDPE pipe DN20 mm PN16	m	500	2000	1000000
Couple HDPE DN90 mm PN16	pcs	19	31400	596600
Couple HDPE DN75 mm PN16	pc	6	22400	134400
Couple HDPE DN63 mm PN 16	pcs	5	10500	52500
Couple HDPE DN50 mm PN16	pcs	2	7100	14200
Tee HDPE 90*90*75 mm PN 16	pcs	5	32500	162500
Control value (Falange) DN125	pcs	1	300000	300000
Control valve (Falange) 90*75	pcs	4	250000	1000000
Washout valve DN75	pcs	4	450000	1800000
bulky meter DN 80mm	pc	1	963109	963109
Reducing socket 80*75	pcs	8	45000	360000
Power invertor	pc	1	150000	150000
Pump	pc	1	1010000	1010000
Solar panel (260W/24v monocrystalline)	pcs	8	600000	4800000
Power cable	m	30	15000	450000

ITEM	UNIT	QTY	RATE	AMOUNT
Reducing socket HDPE DN63*50 mm	pcs	2	14000	28000
Reducing socket HDPE DN75*63 mm	pcs	2	21900	43800
Reducing socket HDPE DN90*75 mm	pcs	6	26200	157200
saddle clamp DN110*20 mm PN16	pcs	5	20100	100500
saddle clamp DN 90*20 mm PN16	pcs	6	9000	54000
saddle clamp DN 75*20 mm PN16	pcs	5	8000	40000
saddle clamp DN 63*20 mm PN16	pcs	7	9700	67900
saddle clamp DN 50*20 mm PN16	pcs	3	6500	19500
End cap HDPE DN75 PN16	pcs	2	2300	4600
End cap HDPE DN63 mm PN16	pcs	2	8600	17200
End cap HDPE DN50 mm PN16	pcs	2	5000	10000
Adaptors HDPE DN75 mm PN16	pcs	4	25100	100400
Adaptors HDPE DN20 PN16	pcs	150	1500	225000
GI pipe DN75 mm	m	9	150000	900000
Tank (elevated)	m^3	1	3000000	3000000

ITEM	UNIT	QTY	RATE	AMOUNT
Expansion storage	m^3	15	813300	12199500
Ball valve	pcs	2	8000	16000
GI elbows 75	pcs	4	32000	128000
GI elbows DN90	PCs	4	41000	164000
HDPE adaptors DN90	pcs	3	31500	94500
cement	bags	184	35000	6440000
sand	tone	42	500000	21000000
aggregate	tone	58	500000	29000000
y16	PCS	185	36000	6660000
strips	pcs	57	8500	484500
BRC	pcs	10	15000	150000
labour 30% of the material cost	slum	1	36101227	36101227
contingencies 10%	slum	1	1564863.6	1564863.6
profit 15%	slum	1	2370052.94	2370052.94
TOTAL AMOUNT				**160373552.5**

4.1.8 Cost benefit analysis of reusing wastewater effluent for no potable application at Uganda Christian university (UCU).

Rising utility costs are significant challenges for institutions in Uganda, including universities. Uganda Christians university consume large volume of freshwater for non-potable applications such as irrigation, toilet flushing, and cleaning. Dependence on National water and sewerage corporation (NWSC) expose the university to high water bills and potential disruption in supply (NWSC, 2023; Nsubuga et at., 2014).

Reusing the treated wastewater effluent for non-potable application creates sustainable solution to reduce fresh water consumption and operational cost in promoting environmental conservation. Cost benefit analysis is and essential tool for carrying out economic viability of the projects by comparing the cost of implementation and operation with the financial benefits arising from reduced water purchases (Boardman et al., 2018; World Bank, 2020).

This study evaluates the feasibility of investing Ugx160373552.5 in wastewater reuse at UCU to assesses potential cost saving, payback period Profitability index and Net present value (NPV) over a ten-year period.

Assess the economic feasibility of the project to inform sustainable management

equation DF= $1/(1+r)^{t}$ (Brigham, E. F., & Ehrhardt, M.C. (2017)

Figure 13:Payback period

#	parameter	%	value
	Capital expenditure (CAPEX)		160373552.5
	Annual operation and maintenance (O&M)	8% of capital expenditure (assumed)	12827004.2
	Unit water price (NWSC institutional tariff)	Ugx4358	

	Project lifetime	10 years	
	Discount rate	11%	
	Daily effluent reuse	$50m^3$/day	
	Annual volume=Daily*365	Small=50*365	18250
	Annual benefit (Avoided water cost) =Volume annual *unit price	18250*4358	79533500
	Net annual benefit= Annual benefit-O&M	79,533,500-12,827,004.2	66,706,495.8
	Payback period=initial investment/annual cash inflow	160373552.5/66,706,495.8	2years,4months ,24days.

Table 11:showing present value using volume of $50m^3$/day

YEAR	DF= $1/(1+r)^t$	PV	NPV
1	0.901	66,706,495.80	60,102,552.72
2	0.812	66,706,495.80	54,165,674.59
3	0.731	66,706,495.80	48,762,448.43
4	0.659	66,706,495.80	43,959,580.73

5	0.593	66,706,495.80	39,556,952.01
6	0.5535	66,706,495.80	36,922,045.43
7	0.482	66,706,495.80	32,152,530.98
8	0.434	66,706,495.80	28,950,619.18
9	0.391	66,706,495.80	26,082,239.86
10	0.352	66,706,495.80	23,480,686.52
			394,135,330.4

NPV=TPV-Cash inflow.

NPV=394,135,330.4-160,373,552.5

NPV=Ugx 233,761,777.9 (using 11% rate for a period of 10 years)

Profitability index (PI)=TPV/initial investment

Pi=394,135,330.4/160373552.5

Pi=2.5

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.0 Conclusion

The higher-pressure nodes may need regulation to prevent excessive pressure and potential pipe damage in low laying areas

The price provided for the quotation is for the present market price for the items, changes may occur during the implementation time.

The analysis indicates that reusing waster effluent at UCU is economical viable

Rapid payback occurs within 2 years 4 months and 24 days, Positive NPV of Ugx 233,761,777.9 (using 11% rate for a period of 10 years)

Cost saving in water bills enhancing financial sustainability

This demonstration in that the investment support water management

Solar energy is preferred as the primary source for pumping the water from contact tank to elevated tank and hydroelectricity power step in case of cloudy days.

5.1 Recommendation

Implement the waste water reuse system using, constructed wetland and polishing units in line with the proposed budget of Ugx 160373552.5

Conduct regular water quality monitoring to ensure safe non-potable reuse accordance with NEMA regulations

The design capacity to be used is $50m^3$/day with the pack back period of 2 years,4 months and 24 days and the present value of NPV=Ugx 233,761,777.9 and profitability index of 2.5 (using 11% rate for a period of 10 yea

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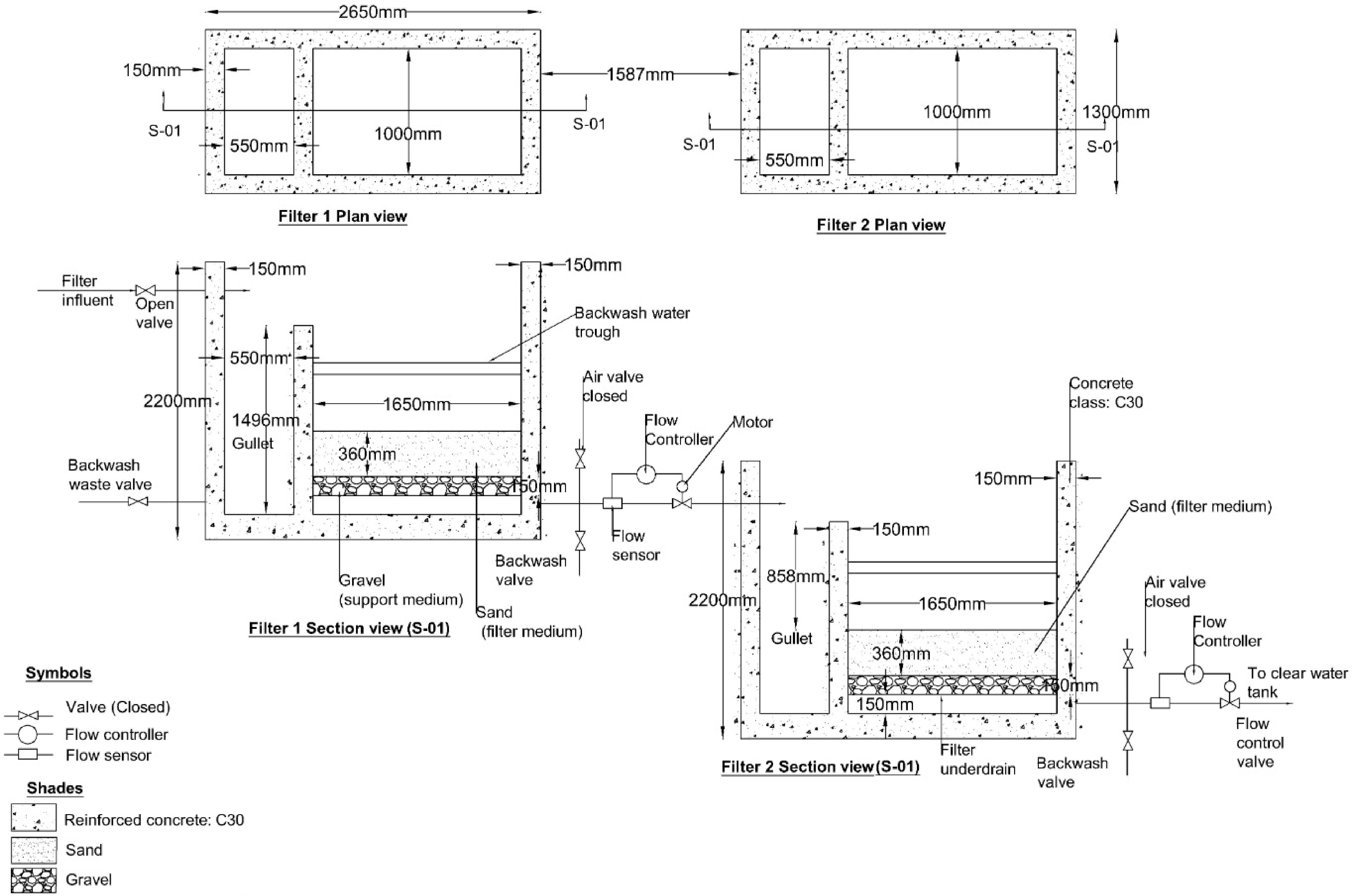

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SCALE:	**1:20 mm**
AUTHORS:	**LOKWANG DOMINIC**
REG. NUMBERS:	**M22B32/021**

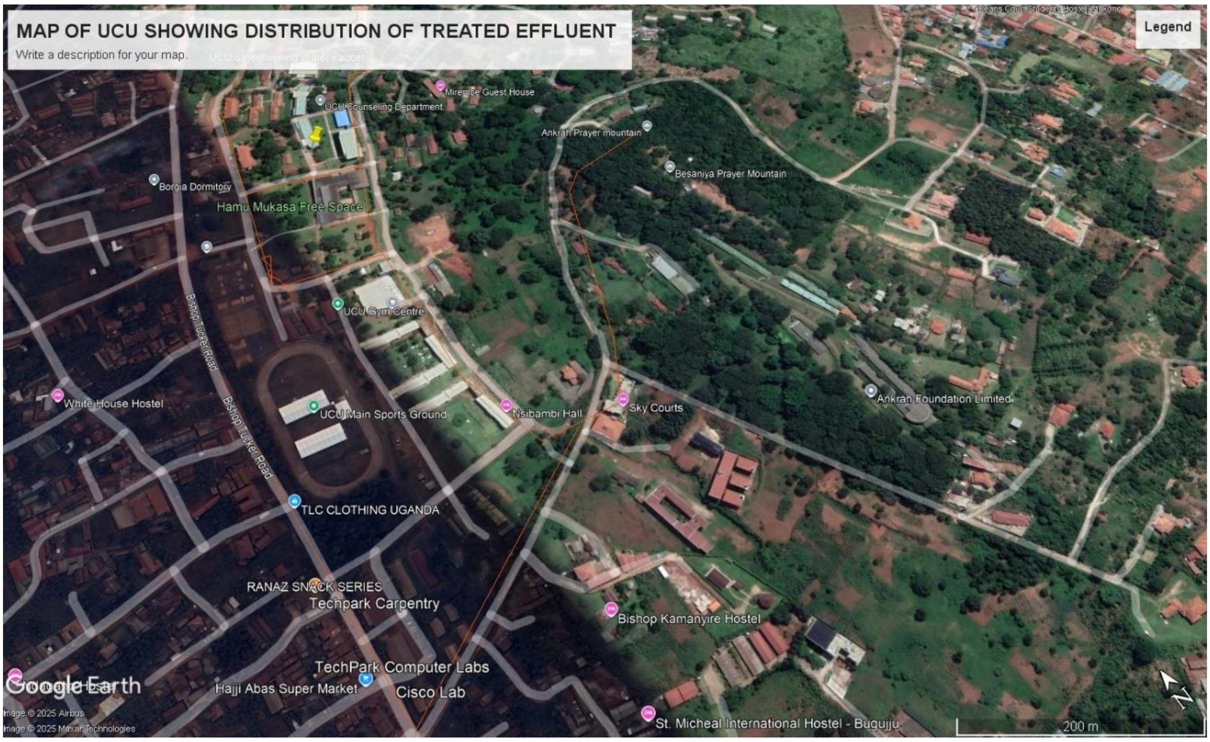

Figure 14: map of ucu extracted using Google earth

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Table 12:showing **price list from Gentex enterprises**

Price List-MRP			
Code	**Name**	**ItemGroup**	**MRP**
1000	20 mm PVC PIPE PN.16	PVC PIPES	4,600
1011	25 mm PVC PIPE PN.10	PVC PIPES	5,700
1012	25 mm PVC PIPE PN.16	PVC PIPES	7,400
1021	32 mm PVC PIPE PN.10	PVC PIPES	9,200
1022	32 mm PVC PIPE PN.16	PVC PIPES	12,000
1031	40 mm PVC PIPE PN.10	PVC PIPES	12,400
1032	40 mm PVC PIPE PN.16	PVC PIPES	17,500
1041	50 mm PVC PIPE PN.6	PVC PIPES	12,600
1042	50 mm PVC PIPE PN.10	PVC PIPES	19,000
1043	50 mm PVC PIPE PN.16	PVC PIPES	27,900
1050	63 mm PVC PIPE LIGHT GAUGE	PVC PIPES	10,800
1051	63 mm PVC PIPE PN.6	PVC PIPES	17,200
1052	63 mm PVC PIPE PN.10	PVC PIPES	28,600
1053	63 mm PVC PIPE PN.16	PVC PIPES	43,800
1060	75 mm PVC PIPE PN.4	PVC PIPES	19,000
1061	75 mm PVC PIPE PN.6	PVC PIPES	24,300
1062	75 mm PVC PIPE PN.10	PVC PIPES	41,600
1063	75 mm PVC PIPE PN.16	PVC PIPES	62,000
1070	90 mm PVC PIPE PN.4	PVC PIPES	22,700
1071	90 mm PVC PIPE PN.6	PVC PIPES	32,300
1072	90 mm PVC PIPE PN.10	PVC PIPES	58,600
1073	90 mm PVC PIPE PN.16	PVC PIPES	87,500
1091	110 mm PVC PIPE L.G (NEW)	PVC PIPES	21,800
1092	110 mm PVC M.GAUGE (1.8 mm)	PVC PIPES	24,800
1093	110 mm PVC H.DUTY-ISO PN.6	PVC PIPES	40,000
5042	50 mm HDPE PIPE PN.6	HDPE PIPES	2,800
5043	50 mm HDPE PIPE PN.10	HDPE PIPES	3,300
5044	50 mm HDPE PIPE PN.16	HDPE PIPES	4,900
5045	50 mm HDPE PIPE PN.20	HDPE PIPES	6,000
5046	50 mm HDPE PIPE PN.25	HDPE PIPES	7,300
5052	63 mm HDPE PIPE PN.6	HDPE PIPES	4,300
5053	63 mm HDPE PIPE PN.10	HDPE PIPES	4,900
5054	63 mm HDPE PIPE PN.16	HDPE PIPES	7,600
5055	63 mm HDPE PIPE PN.20	HDPE PIPES	10,200
5056	63 mm HDPE Pipe PN.25	HDPE PIPES	12,000
5062	75 mm HDPE PIPE PN.6	HDPE PIPES	6,700
5063	75 mm HDPE PIPE PN.10	HDPE PIPES	7,500
5064	75 mm HDPE PIPE PN.16	HDPE PIPES	11,600
5065	75 mm HDPE PIPE PN.20	HDPE PIPES	13,500
5066	75 mm HDPE PIPE PN.25	HDPE PIPES	16,600
5072	90 mm HDPE PIPE PN.6	HDPE PIPES	8,800
5073	90 mm HDPE PIPE PN.10	HDPE PIPES	10,500
5074	90 mm HDPE PIPE PN.16	HDPE PIPES	15,800
5075	90 mm HDPE PIPE PN.20	HDPE PIPES	20,600
5076	90 mm HDPE PIPE PN.25	HDPE PIPES	35,000
5082	110 mm HDPE PIPE PN.6	HDPE PIPES	13,700
5083	110 mm HDPE PIPE PN.10	HDPE PIPES	15,800
5084	110 mm HDPE PIPE PN.16	HDPE PIPES	23,600
5085	110 mm HDPE PIPE PN.20	HDPE PIPES	29,700
5086	110 mm HDPE PIPE PN.25	HDPE PIPES	37,700
5092	125 mm HDPE PIPE PN.6	HDPE PIPES	14,700
5093	125 mm HDPE PIPE PN.10	HDPE PIPES	24,200