USE OF SOLANUM INCANUM FOR WATER TREATMENT AT HOUSEHOLD LEVEL : A CASE OF NAMILYANGO VILLAGE, KISENYI CELL IN MUKONO DISTRICT

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ABSTRACT

Access to clean and safe water remains a challenge as people depend on water from unprotected water sources for domestic use and consumption. This study aimed at the use of Solanum Incanum as a natural disinfectant for water treatment at household level, focusing on Nakyijeera Spring in Namilyango Village. Water quality assessment was carried out in dry and wet seasons with water samples collected in the morning, afternoon and evening. In both seasons, the spring water consistently showed Turbidity, Colour and Total iron values of 0 NTU, 0 PtCo and 0.07±0.00 mg/l respectively. pH ranged from 6.27 to 6.57 and 6.73 to 6.80 in the dry and wet seasons respectively. In the dry season, E. coli values showed 19 CFU/100ml, 14 CFU/100ml, and 14 CFU/100ml, and Total Coliforms of 44 CFU/100ml, 27 CFU/100ml, and 31 CFU/100ml in the morning, afternoon and evening respectively. In the wet season, E. coli of 21 CFU/100ml, 21 CFU/100ml, and 22 CFU/100ml, and Total Coliforms of 48 CFU/100ml, 38 CFU/100ml, and 42 CFU/100ml in the morning, afternoon and evening respectively. The optimum contact time was achieved at 45 minutes, with an optimum dosage of 40ml/l, showing 87% E. coli removal and 86.5% Total Coliform removal. The prototype designed for water treatment showed reduction values of E. coli to 2 CFU/100ml, and 5 CFU/100ml for Total Coliforms. This thus illustrated that Solanum Incanum can be used effectively for water disinfection at household level.

DECLARATION

I hereby declare that this final year research report is a genuine record of my project study. The report is submitted to the Faculty of Engineering, Design, and Technology for the award of a Bachelor of Science degree in Civil and Environmental Engineering at Uganda Christian University.

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APPROVAL

This research project report, handed in by BWAMBALE WILBERFORCE to the Faculty of Engineering, Design and Technology at Uganda Christian University, was carefully supervised and fully prepared under continuous review.

Mr. RODGERS TAYEBWA.

(PROJECT SUPERVISOR)

Signature: …… Date: ……..

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DEDICATION

I dedicate my whole work first to my loving parents, who have kept encouraging me and providing support throughout my academic journey. I also dedicate this to my lecturers, advisors, supervisor, course mates, and my friends whose insight and encouragement have enriched my learning experience and personal growth. Above all, I dedicate this to all the scholars committed to advancing clean and safe water access in underserved areas, that this contribution may spark new ideas and drive practical and lasting change.

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LIST OF ACRONYMS

APHA – American Public Health Association

CFU - Colony Forming Unit

DNA – Deoxyribonucleic Acid

EAS – East African Standards

E. coli – Escherichia coli

H - Height

ISO – International Organization for Standardization

PtCo – Platinum Cobalt

pH – potential of hydrogen

TSS - Total Suspended Solids

ml - milliliter

mg/l – milligrams per liter

m – meters

NTU – Nephelometric Turbidity Units

UNICEF – United Nations Children's Fund

UBOS – Uganda Bureau of Statistics

WHO – World Health Organization

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Globally, access to clean and safe water is a fundamental human right and a cornerstone of public health, socio-economic development, and environmental sustainability, as per Abraham Maslow's Hierarchy of Needs. Water serves various purposes, including domestic activities, agricultural use, drinking, among others. However, approximately 2.2 billion people lack access to safely managed drinking water sources. (WHO, 2022). The situation becomes more severe in developing regions, where the water sources are often contaminated, and the infrastructure for water treatment and distribution is inadequate.

In Africa, approximately 400 million people rely on natural water sources, including surface water, wells, and springs, for their daily water needs. Despite this, the sources are highly susceptible to pollution from agricultural runoff, poor sanitation practices, and industrial waste. (Filipenco. D., 2025). Once these pollutants get access to these water sources, they contaminate them, thus imposing the people using those particular sources to health risks.

Bringing it to Uganda, despite the efforts the Government has made through programs like the National Water and Sewerage Corporation and the Ministry of Water and Environment, access to safe water still remains a challenge, particularly in rural and peri-urban areas. The Water and Environmental Sector Performance Report of 2020 indicates that about 39 % of rural Ugandans rely on natural sources, especially springs, for domestic use. (Ministry of Water and Environment, 2020). While springs are

generally safer, they are still not immune to contamination, especially when surrounded by poor sanitation, infrastructure, and unmanaged land use.

For the aspect of Namilyango Village, Kisenyi cell, located in Mukono District, the residents rely on spring water as their main source of water for drinking, cooking, and other domestic activities. One of the springs located there is Nakyijeera Spring which is commonly used by the residents in this Village. The spring's strategic location makes it easily accessible, making it a preferred water source for the local population. However, the spring is prone to contamination due to surface runoff, agricultural discharge, open defecation, and infiltration.

The conventional water treatment is often unaffordable for low-income households, due to the fact that it’s expensive, promoting interest in naturally occurring, low-cost, locally available, and environmentally friendly alternatives.

The objective of this study, therefore, was to assess the use of *Solanum Incanum* in treatment of water at household level in Namilyango Village. *Solanum Incanum* portrays elements that have shown the ability to disinfect water, showing its potential in the aspect of water treatment. (Rani et al., 2025).

1.2 PROBLEM STATEMENT

The Residents of Namilyango Village, Kisenyi Cell, located in Mukono District, rely on water from springs as their main source of water for consumption and domestic use. However, due to inadequate management of the spring, the water quality has become unsafe for human consumption in this Village.

The laboratory tests of the water from Nakyijeera Spring, an unprotected spring showed that the water is contaminated with E. coli of 16 CFU/100L, Total Coliforms, 48 CFU/100L, Color of 143 PtCo and iron concentration of 1.55mg/L (National Water Quality Reference Laboratory, Entebbe, 2025), which exceeded the East African Standards for Potable water which are 0 CFU/100L, 0 CFU/100L, 50 PtCo and 0.3mg/L respectively. (EAS12; 2018).

The contamination of this unprotected spring is linked to factors such as surface runoff, agricultural runoff, unsafe water collection point, open defecation, and infiltration. These pose serious risks linked to waterborne diseases, particularly in rural communities where access to conventional water treatment methods is limited. (Kihampa et al., 2011).

The purpose of this study, therefore, was to assess the use of *Solanum Incanum* in the treatment of water at household level, since it shows promising potential for improving water quality. (Kihampa et al., 2011).

1.3 OBJECTIVES

1.3.1 MAIN OBJECTIVE

To assess the use of *Solanum Incanum* in the treatment of water at household level.

1.3.2 SPECIFIC OBJECTIVES

1. To determine the physicochemical and bacteriological quality of water from Nakyijeera spring.
2. To determine the optimum dosage of the active components of *Solanum Incanum* powder.
3. To design a suitable water treatment unit for water treatment at household level.

1.4 RESEARCH QUESTIONS

1. What is the physicochemical and bacteriological quality of water from Nakyijeera Spring?
2. What is the optimum dosage of the active components of *Solanum Incanum* powder?
3. What is a suitable water treatment unit for water treatment at household level?

1.5 GEOGRAPHICAL LOCATION

The scope of this study is Kisenyi Cell, Namilyango village, Mukono Municipality in the Central Region of Uganda at coordinates 0°20'03.2"N 32°42'40.8"E, at an elevation ranging from 1134 m to 1299 m above sea level.

1.6 JUSTIFICATION

Accessing clean and safe drinking water is a basic human need. In Kisenyi Cell, Namilyango Village, residents rely on spring water as their main source for domestic use, consumption, and drinking. However, the water was found to have high levels of E. coli and total coliforms, which pose health risks to the community. (National Water Quality Reference Laboratory, Entebbe, 2025). In low-income and informal settings, conventional water treatment methods, such as using alum and chlorine, are often too costly for household-level treatment. (Onyutha & Auma, 2023; WHO/UNICEF, 2023).

This brings us to the aspect of looking for a sustainable alternative. *Solanum Incanum* has the potential to serve as a complementary water treatment agent, especially in rural areas, having portrayed the aspect or ability to disinfect water. (Rani et al., 2025). *Solanum Incanum* contains bioactive components, including saponins (14.4%), Alkaloids (0.6%), Flavonoids (26.7%), and tannins. (Jangra, A., 2025). These compounds are similar to those found in *Moringa* and Neem leaves. (Al-Jadabi et al., 2023).

Saponins have both hydrophilic and hydrophobic parts, which give them a surfactant-like behavior. Once they are added to water, they help in the reduction of the water's surface tension and also destabilize the colloidal particles in water, forming bridges around them, thus causing coagulation. This allows the fine suspended solids and the color-causing particles in water to cluster and settle out. (Moyo et al., 2023).

Tannins, which are natural polyphenols, have multiple hydroxyl groups that enable them to bind very strongly with proteins and polysaccharides. While in water, these tannins neutralize the surface charges of the colloidal particles that are in the water,

bridging them into larger flocs, which settle out easily, aiding coagulation. They have the ability to also bind to microbial cell walls, which leads to microbial inactivation, hence microbial death. (Beltrán-Heredia & Sánchez-Martín, 2009).

Alkaloids such as solanine, found in *Solanum Incanum*, have nitrogen atoms in their structures, which enable them to attract protons once in water, making them positively charged. These are then attracted to the negatively charged microbes, neutralizing their cell envelope. (Musimba, N., 2020). Once they are bound, the alkaloids dive deeper into the lipid bilayer of the microbes, increasing the membrane permeability, leading to the leakage of cell proteins and ions in the microbes' cell membrane, disrupting the microbes' ability to replicate, thus leading to enzyme inactivation, hence microbial death. (Cushnie et al.,2021).

Flavonoids contain hydroxyl and carbonyl groups, making them chemically active against microbes. These groups enable them to bind or attach to microbial enzymes and proteins, which happens through hydrogen bonding, which eventually leads to the inactivation and interference with the normal cell functions. They also have the ability to penetrate through the cells of the microbes and interfere with their DNA replication, thus preventing them from multiplying. (Batiha et al., 2020). In addition to that, flavonoids promote oxidative stress through the aspect of generating reactive oxygen species, weakening the microbial antioxidant defense system, thus leading to damage of their cell membranes, hence microbial death. (Panche et al., 2016).

Solanum Incanum is widely available, making its accessibility easier. With those few explanations, *Solanum Incanum* has shown the potential of being able to treat water at household level.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

In Uganda, water contamination remains one of the most significant issues still being experienced and witnessed, especially in rural areas where the communities mainly depend on untreated water from sources such as springs, wells, rivers, lakes, among others, for various activities such as domestic use, consumption, among others, which might be contaminated. A big percentage of these sources are contaminated with bacteriological contaminants such as E. coli and Total Coliforms. With this rate of contamination, the water can easily cause harm to humans. (Adomi Mbina et al., 2020).

This literature review aimed at giving well-detailed information showcasing the applications of *Solanum Incanum* as both a natural disinfectant in the treatment of the contaminated water from Nakyijeera Spring at Kisenyi Cell in Namilyango Village, found in Mukono District, presenting the different active components of the leaves of *Solanum Incanum*. It also emphasized some research topics that included water quality and treatment, brief information about Nakyijeera Spring, *Solanum Incanum* as a medicinal plant, *Solanum Incanum* as a potential coagulant and disinfectant, the ethanol extraction of the active compounds from the leaves of *Solanum Incanum*, and the optimum dosage of *Solanum Incanum*, among others.

2.2 WATER QUALITY AND TREATMENT

Clean water stands as a basic need for man worldwide however, groundwater continues to get contaminated with aspects of suspended particles, pathogens, and organic debris, among others, and this happens especially in rural areas in underdeveloped and

developing countries. The contamination aspect is normally as a result of agricultural runoff, surface runoff, industrial discharge, infiltration, among others. (Kumpel & Nelson, 2016).

Briefly talking about Nakyijeera Spring, located in Kisenyi Cell in Namilyango Village in Mukono District, the water was found to be contaminated with E. coli and Total Coliforms, which pose a danger to human health.

With that said, therefore, water treatment stands as a very important aspect in ensuring that the drinking water satisfies the WHO guidelines and National Standard Requirements. A standard treatment method consists of phases that commence with coagulation, flocculation, sedimentation, filtration, and finally disinfection. (Farhaoui, M., & Derraz, M., 2016).

Due to the fact that the coagulants and disinfectants are costly, this leaves the researchers with the aspect of looking at naturally occurring, low-cost, biodegradable, and sustainable alternatives that can do the same work as the coagulants and disinfectants that are already in existence.

This drew us deep into the research concerning the use of leaves of *Solanum Incanum* in the treatment of water from Nakyijeera Spring in Namirwango Village in Mukono District. The leaves showcased the existence of coagulation and disinfection properties that would help in the reduction of microbes in the water. (Musyimi, D. M., Ann, A. T., Opande, G., & Emitaro, W. O., 2021).

2.3 BRIEF INFORMATION ABOUT THE NAKYIJEERA SPRING

Nakyijeera Spring is found in Kisenyi Cell in Namiryango Village, located in Mukono District, at coordinates 0°20'03.2"N 32°42'40.8"E, at an elevation ranging from 1134 m to 1299 m above sea level.

It was constructed in 2012 by the Locals, spearheaded by the LC 1. The population of the Village using the spring water are really minimal, around 100 people in the area. During its construction, a plastic container, well-mixed concrete, and hardcore were used to set the spring up. Its depth is 3 feet.

It was identified to stand as a case study area, having found that the spring is unprotected, and the water from this spring contained E. coli and Total Coliforms. (National Water Quality Reference Laboratory, Entebbe, 2025).

The major causes of contamination of this spring are surface runoff, unsafe water collection point, agricultural discharge, open defecation, and infiltration. (WHO, 2017). The spring is also covered by grass, above which harbours contaminants that easily pollute the water of the spring.

2.4 SOLANUM INCANUM AS A MEDICINAL PLANT

Plants having medicinal properties play a great role in the management and cure of many ailments. According to Kumar, D. (2025), the WHO estimates that almost 80% of the world's population utilizes some sort of herbal medicine to treat illness and disease, and natural products are favored over manufactured ones.

Solanum Incanum, one of the 2500 species of the *Solanum* genus that are in existence, is a perennial wild shrub of the Solanaceae family. The plant has rough, velvety leaves with sharp prickles on stems, stalks, and the calyx, and it usually grows 0.4 to 1.5 m tall. The fruits on this plant can measure about 2 to 3 cm in diameter, as they begin green and turn yellowish at maturity. (Rani et al., 2025).

Solanum Incanum consists of bioactive compounds that include Saponins (14.4%), Alkaloids (0.6%), Flavonoids (26.7%), and tannins. (Jangra, A., 2025). The plant normally grows in disturbed soils as a weed along roadsides, buildings, bushlands, forest borders, and overgrazed grassland, among others. (Opande, G., 2021).

Solanum Incanum is used widely in Africa as traditional medicine to treat various ailments, which are sore throat, headache, liver pain, fever, stomach disorders, painful menstruation, snake bites, skin problems, asthma, diabetes, hypertension, malaria, among others. (Nostro et al., 2000). The leaf pastes of this plant are applied to wounds, bruises, warts, and rashes for their antimicrobial and anti-inflammatory properties. In Taiwan, it is used as a conventional medication for hepatitis. (Mwaura et al., 2020).

When it comes to Europe, the decoctions of the plant parts treat dermatophilosis, foot rot, and other livestock infections (Abebe et al., 2014). With those few properties and abilities, Solanum Incanum stands a chance to be referred to as a medicinal plant.

2.5 *SOLANUM INCANUM* AS A POTENTIAL COAGULANT AND DISINFECTANT

Research shows that *Solanum Incanum* can reduce the aspect of turbidity and reduce the microbial content in water up to 99% in treatment experiments, making it suitable to be used as an alternative for water treatment at household level. (Githaiga et al.,

2019). It contains saponins, tannins, alkaloids, and flavonoids, which are similar to the compounds found in Moringa. (Al-Jadabi et al., 2023).

Flavonoids possess both hydroxyl and carbonyl groups that make them chemically reactive against microbes. They bind to enzymes and proteins through hydrogen bonding, interrupting the normal activities of the cells. (Batiha et al., 2020). In addition to that, flavonoids can enter microbial cells and interfere with the DNA replication, stopping them from multiplying. (Panche et al., 2016).

Tannins are polyphenolic substances with numerous hydroxyl groups that give them a strong ability to bind with proteins and carbohydrates. In aqueous solutions, they help neutralize the surface charge of colloidal matter, leading to the formation of heavier flocs that settle more easily. Their binding properties also enable tannins to attach to microbial cell walls, weakening and destroying them, which results in microbial inactivation. (Beltrán-Heredia & Sánchez-Martín, 2009).

Saponins contain both water-loving and water-repelling compounds (hydrophilic and hydrophobic compounds, respectively) within their structure, which allow them to behave like surfactants in water. Once they are introduced into water, they lower the surface tension and interfere with the stability of the colloidal particles. This disturbance causes the particles to come together, thus forming larger clusters that settle out, aiding coagulation. (Moyo et al., 2023).

Alkaloids contain nitrogen atoms that gain positive charges in water. These positively charged molecules are attached to the negatively charged microbial membranes, destabilizing them and allowing the alkaloids to move into the lipid layers. This

penetration increases the permeability of the cell, causing essential materials to leak out and enzymes to lose function, eventually killing the microbes. (Musimba, 2020; Cushnie et al., 2021).

NOTE: Although the leaves of the plant showcase both coagulation and disinfection ability, the research focused more on disinfection due to the contaminants that were found in the water. E. coli and Total Coliforms were found to be abundant in the water at the Nakyijeera Spring. The water had no turbidity and color in it.

2.6 THE EXTRACTION OF THE ACTIVE COMPOUNDS OF *SOLANUM INCANUM* POWDER

The choice of the solvent needed to extract the active compounds can significantly impact their concentration and efficiency, looking at the fact that solvents like ethanol and methanol are greatly more effective in extracting wider ranges of bioactive compounds from Solanum Incanum powder compared to water. (Sbhatu & Abraha, 2020).

The leaves were obtained from Namilyango Village, along the Railway line. Washed with a soft brush and distilled water and partially dried for one day. They were then oven-dried for 24 hours at 60^{o}C. A grinder was later used to smash the dry leaves into powder, and a 600-micrometer sieve for fine powder.

The powder was later immersed in distilled water for 30 minutes, with occasional shaking. Later filtered to attain the filtrate that contained the active bioactive compounds. It's the filtrate that was used in determining the optimum dosage of the *Solanum Incanum* powder and the optimum contact time at which significant microbial reduction was achieved.

Water was chosen for extraction because it is safe, accessible, and suitable for practical household water treatment. Unlike ethanol, water is non-toxic, inexpensive, and environmentally friendly, making it appropriate for low-resource settings. (Won & Kwon, 2024). Additionally, using water eliminates the risk of solvent residue contamination in the treated water. (Kirui et al., 2015).

Scientifically, water extracts polar bioactive compounds such as saponins, flavonoids, glycosides, and tannins, which are responsible for the antimicrobial activity against E. coli and Total Coliforms. (Ilori et al., 2023). Because it extracts fewer non-polar compounds, potentially toxic constituents, the aqueous extract generally exhibits lower toxicity than the ethanol extract. (Won & Kwon, 2024).

Furthermore, the aqueous extraction is simple and replicable, which allows the community people to prepare the disinfectant locally without dependence on expensive or flammable solvents, which ensures scalability and sustainability of the treatment process. (Adeyemi et al., 2021).

2.7 DETERMINING THE OPTIMUM DOSAGE OF THE *SOLANUM INCANUM* POWDER

Here, the contact time experiment was done to help determine the lowest dose of the extract that would give the best microbial reduction at a practical contact time. The percentage reduction helped in determining the minimum contact time in which the biggest percentage of microbes were removed, and also the minimum dosage of the extract needed to kill the microbes in the practical contact time obtained.

2.8 HOW OTHER PEOPLE HAVE DONE THEIR RESEARCH IN WATER TREATMENT USING *SOLANUM INCANUM* EXTRACTS

Starting with the research that was issued by Kihampa Charles and his colleagues, who wrote a paper report showcasing the performance of *Solanum Incanum* as a coagulant and a disinfectant for water purification, using the leaves, stem, and root extracts. The coagulation flocculation experiment was carried out with the use of a Phipps and Bird PB-700TM Jar Tester. The results showed that turbidity removals were 96%,97%, and 75% for raw water with turbidity of 450 NTU, 300 NTU, and 105 NTU, respectively, showing that it can work as a solution in turbidity-related waters. Then, for fecal coliform, it displayed a maximum removal of 99% at $2.2 * 10^{-4}$ g/ml. The LD50 ranged from $0.62 – 2.6 * 10^{-5}$ g/ml. the results suggested that *Solanum Incanum* is a promising disinfectant and coagulant for water purification. (Kihampa et al., 2011).

In addition to that, the other research was done by Waithaka Paul and his colleagues, entitled the antibacterial effect of *Solanum Incanum* root extracts on bacteria isolated from portable water. Here, they used methanol for antimicrobial effectiveness. Staphylococcus Aureus removal showed 85%, registering the greatest reduction. Pseudomonas Aeruginosa removal recorded 80%, Bacillus Subtilis removal showed 82%, Escherichia Coli removal showed 78%, whereas Klebsiella species showed the lowest percentage removal with 70%. These percentages indicated that the root extracts also exhibited strong antibacterial activity. (Waithaka et al., 2019).

Furthermore, Desta Berhe Sbhatu and his colleague made and published their research paper entitled, Preliminary Antimicrobial Profile of Solanum Incanum. This paper looked at the phytochemical characteristics and the antimicrobial activities of ethanol

and aqueous extracts of fruits, leaves, and stems of *Solanum Incanum*, against Gram-negative (Salmonella Typhi and E. coli) and Gram-positive (Staphylococcus Aureus and Bacillus Subtilis) bacteria. It's shown in the paper that Phytochemical screening of the leaves, fruits, and stem extracts of *Solanum Incanum* indicated that it is the source of the bioactive compounds, which are alkaloids, glycosides, saponins, steroids, and tannins. Ethanol extracts showed superior antimicrobial performance than aqueous extracts. Inhibition zones from the ethanol leaf extracts ranged from 13.34mm to 16.06mm which were corresponding to 72 to 100%, showing a greater microbial removal. Then, for water extracts, the inhibition zones were between 10.45mm to 14.02mm, equivalent to 67 to 90% effectiveness. This paper proved that both ethanol and water showcased antimicrobial abilities. (Sbhatu D.B., 2020).

2.9 THE TOXICITY NATURE IN THE SOLANUM INCANUM POWDER

Solanum Incanum contains steroidal glycoalkaloids like solanine, which help in the antimicrobial activity and still contribute to the aspect of toxicity in the plant. They interact with the sterols, found in the cell membranes, hence leads to disruption of the membrane integrity, increased permeability, and cell lysis. (Almajan et al., 2008). Reports that have been done by different scholars show that these compounds can also interfere with the acetylcholinesterase activity, thus inducing neurological symptoms when they are ingested in large amounts. (Friedman, M., 2006).

When it comes to the Lab studies, there is evidence that the plant has toxic properties when tested on mammalian cell systems. The extracts from ethanol and aqueous have shown measurable cytotoxicity towards Vero cells, which indicates that high concentrations can damage and eventually kill animal cells. (Kihampa et al., 2011).

Several other investigations have shown that these compounds can trigger apoptosis through mitochondrial disruption. (Milner et al., 2011).

All in all, studies on toxicity also indicate that *Solanum Incanum* extracts pose a low risk at moderate doses. This means that, as it's being used for household water disinfection, dosage optimization is crucial to ensure that microbial reduction is achieved without leaving harmful levels of glycoalkaloids in the treated water. (Saidu et al., 2011).

2.10 THE WATER TREATMENT PROCESS AT HOUSEHOLD LEVEL

Since the water was not turbid and had no color, the treatment system consisted of a disinfection chamber and a storage chamber with a collection point.

Disinfection of water is the process that results in the inactivation, destabilization, and destruction of the cell membranes of microbes in water. (WHO, 2022). In the disinfection chamber, that’s where the microbial destruction occurred using the *Solanum Incanum* dosage from the aqueous solution, at the practical contact time attained. The water was then left to flow to the storage chamber through the pipeline network.

The storage chamber helped in storing the disinfected water to prevent it from recontamination. For storage, a clean 5-liter jerrycan was used to store the water for further analysis.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

This chapter outlines the procedures and methods used to achieve the study's main objective or cause. It covers how raw water was collected from Nakyijeera Spring, the various physicochemical and bacteriological tests performed on the raw water from Nakyijeera Spring, the methods used to extract the bioactive compounds from *Solanum Incanum* powder, and the optimal dosage of *Solanum Incanum* powder.

3.1.1 RESEARCH DESIGN

The following stand as the steps or procedures that were followed in trying to accomplish or attain data during the research.

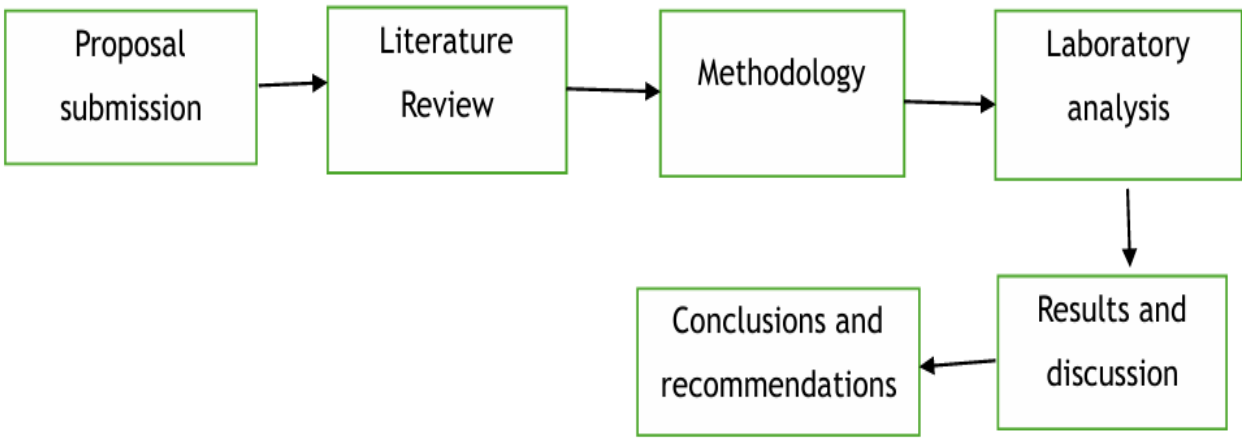


Figure 1: The Research Design

3.2 DETERMINATION OF THE PHYSIOCHEMICAL AND BACTERIOLOGICAL QUALITY OF NAKYIJEERA SPRING WATER

3.2.1 COLLECTION OF THE WATER SAMPLE FROM NAKYIJEERA SPRING

Following the standard operating procedures of sample collections, safety gears were first prepared, which included gloves, a reflector jacket, safety boots, a mask, and a helmet to avoid external contamination from the surrounding.

Clean plastic sampling bottles were obtained. These bottles were cleaned with distilled water to prevent contamination during water sample collection.

A cooler box was obtained, which helped maintain the sample temperature at that of the source to prevent microbes from multiplying or dying off, thus preventing sample deterioration. The ice in the cooler box was kept below 4°C, to prevent sample deterioration.

On arrival at the water source, the sampling bottles were rinsed using the water from Nakyijeera Spring, and then water samples were collected in triplicates (morning, afternoon, and evening), that is, 6 am, 2 pm, and 6 pm, and in situ parameters like pH and temperature were measured.

Samples were collected three times a day, that's morning, afternoon, and evening, at 6 am, 2 pm, and 6 pm respectively. For the dry season, samples were collected on 29th August 2025, 3rd September 2025, and 4th September 2025. Then, for the wet season, samples were collected on 22nd September 2025, 23rd September 2025, and 24th September 2025.

The spring water was sampled in both the wet and dry season, basing on the seasonal calendar of the Region from the Ministry of Water and Environment. (MWE, 2025).

The main reason for sampling in three days was to get a better representation of a particular season for the selected tests.

Being a one-point source, we carried our samples in a 5-litre clean sealed plastic bottle, which was placed in a cooler box, and then transported to the laboratory for analysis using a motorcycle.

For the bacterial aspect, the tests needed to be carried out within 6-24 hours to prevent sample deterioration and also ensure accurate results.

3.2.2 TURBIDITY (HACH 8195)

Turbidity was measured because it correlates with particulate-associated microbes and reduces the effect of disinfection; thus, knowing its levels is important as it evaluates the clarity of water by measuring the amount of suspended particles. High turbidity may indicate the presence of suspended solids, microorganisms, or other contaminants that reduce water quality and interfere with disinfection processes.

A turbidimeter was used, which measures light that is scattered at 90 degrees by suspended particles.

Procedure

- The Turbidimeter was first calibrated, ensuring that its measurements to its standards.

- The sample was then collected, and a small portion was placed in a clean cell until the lower part of the meniscus was touching the cell's line of reference, which was then cleaned to ensure that light could easily pass through it without any disruptions.
- The cell was then placed in the turbidimeter, covered, and then the read button was pressed.
- The results were recorded in Nephelometric Turbidity Units (NTU).
- The procedure was repeated two more times.

3.2.3 COLOR (HACH 8025)

Looking at the spring, the presence of unusual colour could strongly suggest the presence of decaying organic matter and other contaminants in the water. As we checked for colour, we were able to know the kind of suspended particles that are in Nakyijeera Spring water.

For the measurement aspect, a spectrophotometer U3900 was used to measure colour and PtCo. were the units used.

Procedure

- The spectrophotometer was first calibrated to ensure that it could work based on the required standards.
- The water sample was then powered in rectangular cells, which were later cleaned to complete dryness.
- The cells were then placed in the spectrophotometer, covered, and then pressed read, and left to run.

- The results were recorded in PtCo. Units.
- The procedure was repeated two more times, and the results were recorded.

3.2.4 TOTAL SUSPENDED SOLIDS (TSS) (ISO 11923:1997)

The purpose of the TSS test was to measure the concentration of undissolved solids in water, which can reduce water clarity and quality. High levels of TSS can impact the efficiency of water treatment processes and increase the likelihood of harboring harmful microorganisms.

Procedure

- Water was filtered, using a pre-weighed glass fibre filter.
- The solids that were retained on the filter were then dried at 105°C and weighed.
- The increase in the weight gave the TSS concentration, reported in mg/L.
- This was repeated two more times, and the results were recorded.

3.2.5 pH (US ISO 10523)

The purpose of the pH test was to measure the acidity or alkalinity of the water, due to the aspect of hydrogen ion concentration.

The test was conducted using a pH meter.

Procedure.

- The pH meter was calibrated first to the known and recognized pH value units.

- ❖ The water sample was then poured into the pH meter cover, and then the calibrated electrodes of the pH meter were immersed in the water, covered, and then allowed to stabilize for one minute.
- ❖ After stabilizing, the reading was recorded. The pH electrodes were then cleaned to avoid contamination.
- ❖ This was then repeated two more times, and the results were recorded.

3.2.6 E. COLI (COLILERT- 18/ APHA- 9222B)

E. coli is a type of bacteria, found in the intestines and feces of warm-blooded animals and humans. It is measured in CFU/100mL.

Equipment needed

1. Filter membrane.
2. Culture media (MacConkey agar).
3. Reagents like Alcohol.
4. Incubator.
5. Disinfectant clips.
6. Incubator.
7. Agar plates.
8. Beakers.
9. Stove.

Procedure

- ❖ The collected water sample was filtered through a membrane filter
- ❖ The membrane filter was then transferred to a MacConkey agar plate.
- ❖ The membrane filter was incubated at 36°C for 24 hours.

- After 24 hours, the chromogenic coliform agar plate was removed from the incubator, and the colonies were counted and then transferred using a wire loop to a slide.
- The slide was then gently stained with crystal violet and left to settle for 1 minute, and then gently washed off with tap water.
- The slide was gently stained with iodine and left to settle for one minute, after which it was washed off using tap water. Iodine stabilizes the stain by increasing the cell's affinity to the stain
- Alcohol was then added drop by drop to the slide until it ran almost clear; thereafter was washed off gently using tap water. Alcohol decolorizes the cells by removing protein from the cell membrane.
- The slide was then stained with safranin and left to settle for about 45 seconds, then washed off with tap water.
- The slide was left to dry and then observed under a microscope, and the total coliform bacteria are the sum of oxidase-negative colonies with pink to red colour and all dark blue.

3.2.7 TOTAL COLIFORMS (APHA METHOD 9222)

The purpose of testing for total coliforms was mainly to determine the presence of bacterial contamination, which may indicate fecal pollution and potential health risks.

The test was performed using the Membrane Filtration Method, just the same method for determining E. coli, apart from the fact that for Total Coliforms, Vector Coliform Agar was used as the culture medium.

It was also measured in CFU/ 100ml.

3.3 DETERMINATION OF THE OPTIMUM DOSAGE OF THE ACTIVE COMPOUNDS OF *SOLANUM INCANUM* POWDER

This showed how the optimum dosage of the *Solanum Incanum* powder was obtained, starting from the stage of collecting the leaves, up to the stage of obtaining the concentrated powder needed for disinfection.

3.3.1 ACQUISITION OF THE POWDER OF *SOLANUM INCANUM*

Equipment used

1. Knife.
2. Gloves.
3. An empty box.
4. Grinder.
5. Sieve
6. Soft brush.
7. Oven.

Procedure

- Leaves were obtained from the Kisenyi cell along the railway, cut using a knife, and collected in an empty box for easier transportation.
- They were later cleaned using a soft brush and distilled water to remove contaminants like dust that had fallen on them.
- The leaves were then placed under the sun for a day to partially dry them.
- The leaves were then oven-dried for 24 hours at 60°C to completely dry them and remove the moisture.

- The leaves were ground in a grinder, sieved using a 600-micrometre sieve to remove coarse particles for uniform mixing, and stored for further analysis.

3.3.2 EXTRACTION OF THE ACTIVE COMPOUND OF *SOLANUM INCANUM* POWDER

Equipment used

1. Distilled water.
2. Filter paper.
3. Weigh balance.

Procedure

- 10 grams of fine *Solanum Incanum* leaf powder was infused (soaked) in 1000 ml of water and stirred for 30 minutes to ensure complete dissolution and maximum extraction of the bioactive compounds.
- The extract was then filtered using Whatman No. 1 filter paper.
- The plant residue was discarded into the environment. Since it's a plant residue, it was used for activities like mulching as it added organic matter into the soil, acting as a fertilizer.
- The extract solution was then kept for further analysis.

3.3.3 DETERMINATION OF THE OPTIMUM DOSAGE OF *SOLANUM INCANUM* POWDER

For optimum dosage, the contact time experiment was carried out. The goal of this experiment was to determine the lowest dose of Solanum Incanum leaf extract that gives the best microbial kill at a practical contact time.

Equipment

1. Contaminated water from the spring.
2. Sterile beakers
3. Petri dishes.
4. Culture media.
5. Stirrer.
6. A timer.

Procedures

3.3.3.1 For contact time

- Water was collected from Nakyijeera Spring, and the initial values of E. coli and Total Coliforms were obtained.
- 6 Beakers of 1000ml were filled with the raw water and were dosed with a certain dose of the extract.
- They were then left to stand for certain time intervals, that is 0,15,30,45,60, 75, and 90 minutes.
- The solution was then neutralized using sodium thiosulfate to stop further disinfection. This helped in getting results that reflect disinfection within the specified contact time interval.
- Once the time was done, the water was then filtered using the filter membrane, and the remains on the filter were scraped off and then placed on the Culture media agar plates and incubated for 24 hours at 36°C to allow microbes to grow.
- The values of E. coli and Total Coliforms were recorded.
- Percentage reduction was calculated by;

Percentage reduction = ((initial count – current count)/ (initial count)) * 100%

- The results were then plotted with microbial percent reduction against contact time.
- The contact time that showed significant microbial reduction was then selected as the optimum contact time.
- The procedure was repeated two more times and averaged to get a better representation.

3.3.3.2 For optimum dosage of the extract.

- Water was collected from Nakyijeera Spring, and the initial values of E. coli and Total Coliforms were obtained. The values of pH, turbidity, and colour were also recorded.
- 11 beakers labelled with A, B, C, D, E, F, G, H, I, J, and K They were later filled each with 1000ml of water.
- Beaker A was posed as a negative control, showing the present state of the water when the powder extract was not present.
- The beakers, B, C, D, E, F, G, H, I, J, and K, were dosed with 10ml, 20ml, 30ml, 40ml, 50ml, 60ml, 70ml, 80ml, 90ml, and 100ml, respectively.
- The beakers were then stirred for 30 – 60 seconds to ensure uniform mixing.
- The beakers were then covered to avoid contamination and left to stand for a controlled contact time, as attained above.
- The solution was then neutralized using sodium thiosulfate to stop further disinfection. This helped in getting results that reflect disinfection within the specified contact time.

- Once the time was done, the water was then filtered using the filter membrane, and the remains on the filter were scraped off and then placed on the Culture media agar plates and incubated for 24 hours at 36°C to allow microbes to grow.
- The values of E. coli, Total coliforms, Turbidity, colour, and pH, after disinfection were attained and recorded.
- The dosage that was found to be the best option, showing better measures of physical, chemical, and biological qualities of water after disinfection, was then selected as the optimum dosage.
- To calculate the percentage reduction, the following method was used;

  Percentage reduction = ((initial count – current count)/ (initial count)) * 100%

3.4 DESIGNING A SUITABLE WATER TREATMENT UNIT FOR WATER TREATMENT AT HOUSEHOLD LEVEL

In reference to the Water Supply Design Manual,2013, a water treatment unit was designed using AutoCAD, and a prototype was later made.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter takes us through the results obtained and their comparison with previous researchers' work. Lab tests were carried out at the National Water Quality Reference Laboratory in Entebbe, Uganda Christian University Lab, and the National Water and Sewerage Corporation Central Laboratory in Bugolobi.

4.2 PHYSICOCHEMICAL AND BACTERIOLOGICAL QUALITY OF THE RAW WATER.

The tests that were carried out were turbidity, pH, E. coli, Total Coliforms, Temperature, Total iron, and Color. These were carried out on both the wet and the dry seasons.

4.2.1 TURBIDITY

Turbidity is the cloudiness of water caused by suspended particles, measured in NTU. The turbidity of the spring water in both wet and dry seasons was 0 NTU.

This is because groundwater normally goes through natural filtration, as it is infiltrating through the layers, that include soil, sand, gravel, and fractured rocks, which act as a physical cleaning system, removing the suspended particles, via adsorption, and sedimentation. (Griebler & Lueders, 2009). These help in trapping the aspects of clay, organic debris, silt, and microbes, since water moves slowly through those layers.

Although after communicating with the locals, it was discovered that some days when it rains heavily, they sometimes collect turbid water. This indicates that the turbidity is caused by surface runoff and infiltration. But before it's used, they first leave it to

settle for like 10 minutes, then use the clear water and discard the particles at the bottom.

4.2.2 COLOUR

For the samples attained in both the wet and dry seasons, the results for colour were 0 PtCo Units for both seasons.

This is because during the slow movement of water underground, the substances that always bring about water colour are removed. As rainwater finds its way into the soil, colored organic molecules are adsorbed on the minerals of clay, carbonate surfaces, and iron oxides, thus removing brownish tannins that would cause color in the water. (Blumberg et al., 2016). In addition to that, the presence of low oxygen underground helps in keeping metals like iron in their stable form, which prevents the development of yellow and reddish tones that would cause color in the water. (Rostad et al., 2003).

4.2.3 TEMPERATURE

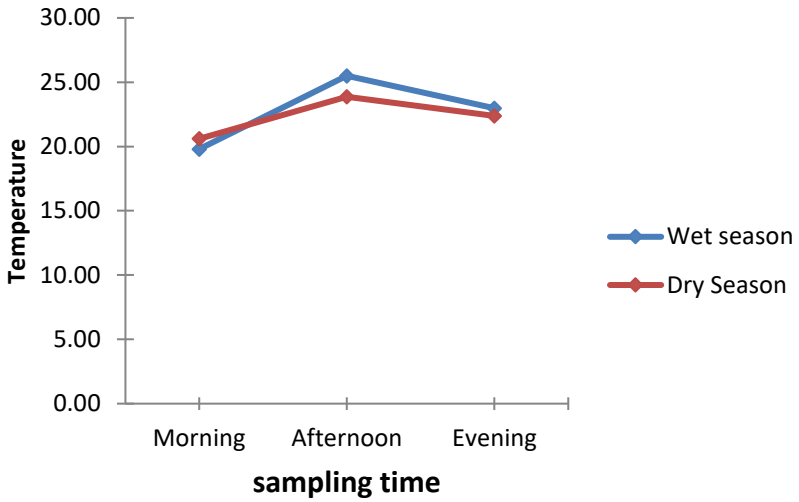


Figure 2: Temperature variations in both seasons

The temperature variation for the dry season was (20.60±0.78, 23.87±0.35, and 22.37±0.61) degrees celsius, while for the wet season, it was (19.80±2.85, 25.5±4.12, and 22.97±4.43) degrees celsius for morning, afternoon, and evening, respectively.

This is due to the aspect of hydrological and geological controls that keep influencing the groundwater system. The morning temperatures were low because the aquifer and the soil lose heat in the night hours due to the absence of solar radiation, which allows the groundwater near the Nakyijeera Spring outlet to equilibrate to cooler ambient conditions. (Mukherjee et al., 2015).

Afternoon temperatures were seen to increase because the heat is conducted through the upper soil layers, warming the spring water coming out during the peak solar intensity hours. (Taylor & Howard, 1996). Looking at the high temperatures in the wet season, it is because rainfall normally enters the ground at temperatures between 20 –

250 °C in tropical regions, which is warm. Thus, this warm recharge brings about the rise of temperatures of the aquifers during high infiltration periods. (Oke et al., 2002).

In the evening, the subsurface retained the heat that had been absorbed during the day, causing the groundwater to release the stored heat as it flows to the spring gradually. That's why the temperatures decline slowly rather than a sharp drop. (Taylor & Howard, 1996).

4.2.4 pH

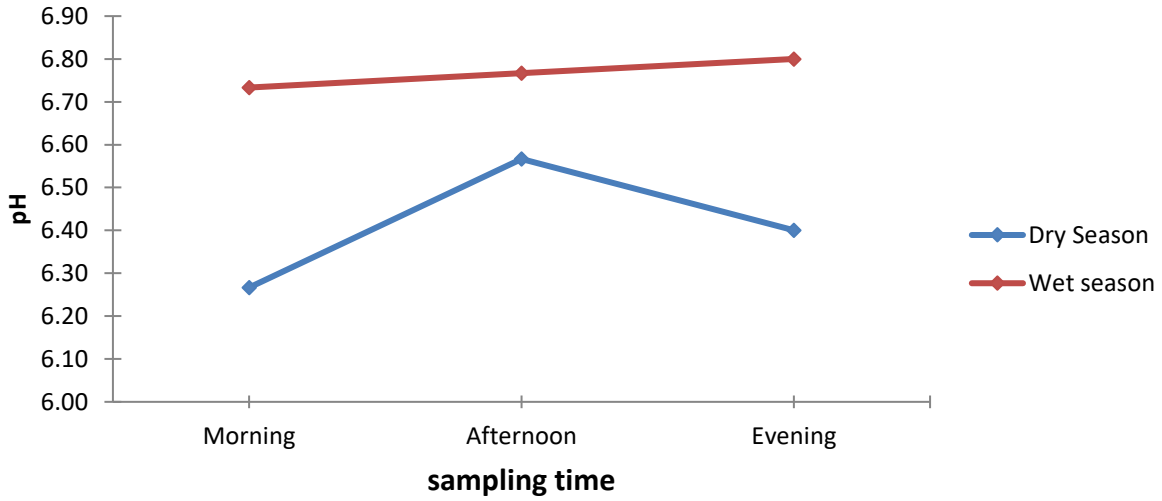


Figure 3: pH variations in both seasons

The pH recorded in the dry and wet seasons was (6.27 to 6.40) and (6.73 to 6.80), respectively. These pH values for the wet season are within the acceptable range of 6.5 to 8.5. For the dry season, the pH values are not within the acceptable range of potable drinking water.

It can be seen that during the dry season, pH is slightly acidic. This is because of the decomposition of organic matter and root respiration of the vegetation that is around

the spring, which releases carbon dioxide. This carbon dioxide dissolves in water, forming a weak acid, which is carbonic acid, thus lowering the pH. In addition to that, there is minimal recharge to dilute the acids in the water, keeping the pH slightly acidic. (Kumpel & Nelson, 2016).

In the wet season, the pH of the spring water becomes more neutral compared to that in the dry season. This is because an increase in rainfall and groundwater recharge leads to dilution of the acidic ions and washes away the decomposing organic matter, thus reducing acidity. (Colin Carreno et al., 2023). In addition to that, continuous flow brings about aeration, which allows carbon dioxide to escape, reducing the carbonic acid concentration, thus the pH shifts to neutral. (Rostad et al., 2003).

4.2.5 TOTAL IRON

The total iron recorded over the two seasons was the same, and it was 0.07±0.00 mg/l for morning, afternoon, and evening, respectively. This is because the water originates from a stable geological ground source. The spring water comes from a stable subsurface aquifer that has very few interactions with iron-bearing minerals and surface runoff. (Faye et al., 2023). Furthermore, the spring has a continuous flow which prevents stagnation, thus reducing oxidation reaction, which could lead to the release of dissolved iron in water.

4.3.6 E. COLI

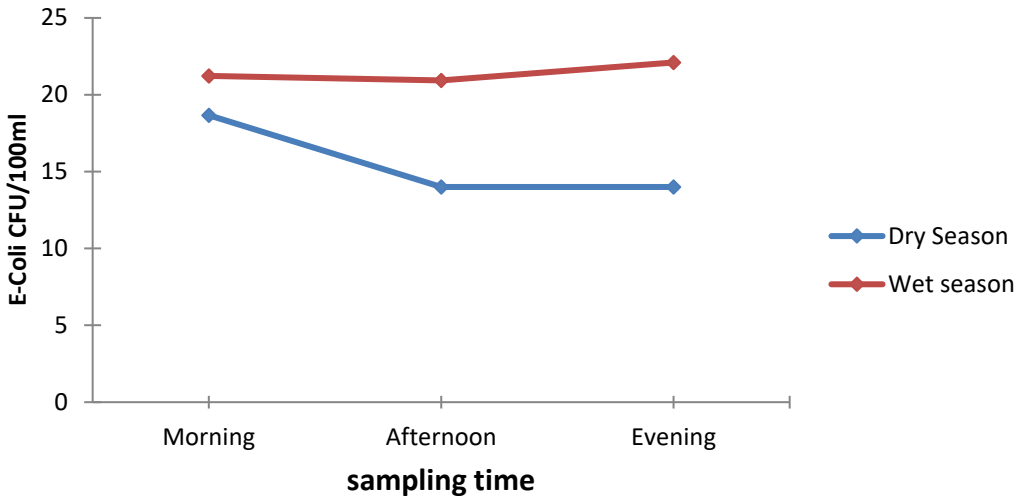


Figure 4: E. coli variations in both seasons

The E. coli for the dry season was recorded to be (19 CFU/100ml, 14 CFU/100ml, and 14 CFU/100ml), and for the wet season was (21 CFU/100ml, 21 CFU/100ml, and 22 CFU/100ml), for morning, afternoon, and evening, respectively.

These are all above the recommended standards for potable water, which are 0 CFU/100ml. The variations were influenced by temperature stress, UV radiation exposure, and microbial introduction into the water due to surface runoff and the existing vegetation around the spring.

The overnight cooling normally favors microbial survival in the present state, and the stagnant situation around the spring allows the microbes to persist, leading to relatively high concentrations in the morning. (Kihampa et al., 2011).

In the afternoon, the temperature of the spring water increases. Ultraviolet radiation damages the DNA of the microbes, inhibiting their replicating mechanism, hence

microbial death. This brings about the reduction of E. coli in the afternoon. (Faye et al., 2023).

When it comes to the evening hours, the temperatures drop, and there is an introduction of microbes in the water from the vegetation above the spring, which traps water from surface runoff, which is why the level of contamination increased even when there were no favorable conditions for microbial growth. (Besmer et al., 2017).

The E. coli counts in the wet season are higher than those in the dry season, due to increased surface runoff, which introduces more contaminants from the animal waste, soils, and the decomposing organic matter around the spring.

4.3.7 TOTAL COLIFORMS

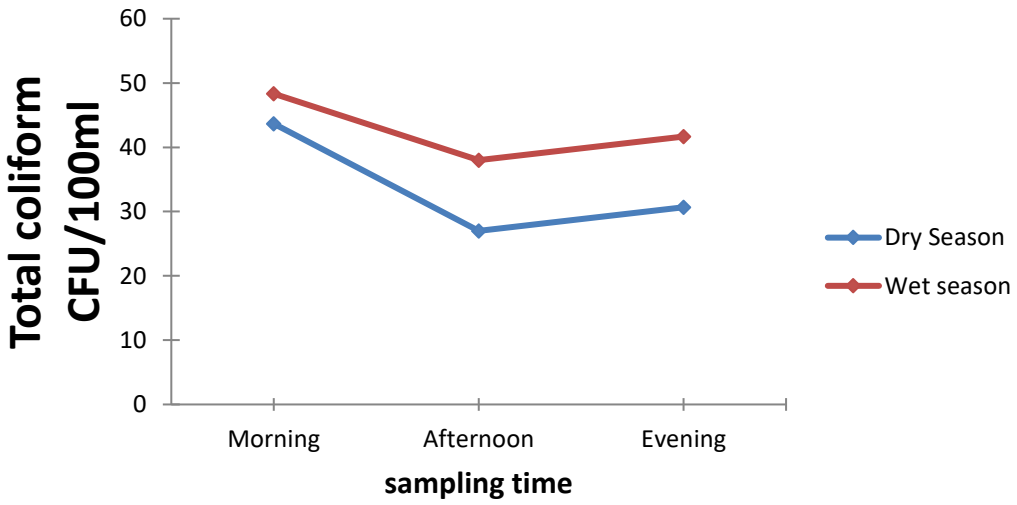


Figure 5: Total Coliform Variations in both seasons

In the dry season, Total Coliforms were (44 CFU/100ml, 27 CFU/100ml, and 31 CFU/100ml), and in the wet season, the results recorded were (48 CFU/100ml, 38 CFU/100ml, and 42 CFU/100ml), for morning, afternoon, and evening, respectively.

These are all above the recommended standards for potable water, which are 0 CFU/100ml.

The continuous accumulation of microbes that are introduced into the spring from the surrounding vegetation overnight leads to the aspect of high concentrations in the morning hours. (Faye et al., 2023).

Looking at the afternoon times, the elevated temperatures lead to UV stress, DNA damage, leading to Coliform death. (Besmer et al., 2017).

In the evening, with reduced UV intensity, the release of microbes from the vegetation around the spring, the microbe level tends to rise, that's why the Total Coliform counts tend to rise in the afternoon. (Kumpel & Nelson, 2016).

Note: Groundwater is usually considered microbial free due to the soil and geological layers that act as natural filters, and a physical cleaning system, removing the suspended particles, via adsorption, and sedimentation. (Griebler & Lueders, 2009). However shallow aquifers and springs can easily be contaminated due to animal water and poor sanitation as contaminants travel through cracks, porous soils and preferential flow paths. (WHO, 2017). Studies in East Africa show that most springs in rural areas frequently register E. coli and Total Coliforms due to the aspect of their proximity to households, livestock and sanitation facilities. (Jimenez & Chaidez, 2015).

Looking at Nakyijeera Spring, it is likely to be fed by a shallow weathered basement aquifer, which is common in Mukono District. (Howard et al., 2003). Studies in the region show that most groundwater occurs in the upper weathered regolith and fractured bedrock, having active groundwater zones that are found within the range of top 5 to 15 m of the subsurface of shallow springs. (Taylor, R., 1996). This depth is supported by the Nakyijeera Spring behavior, that shows rapid changes in microbial counts within seasons, an indication of limited natural filtration.

4.4 DETERMINATION OF THE OPTIMUM DOSAGE OF THE ACTIVE COMPOUNDS OF THE POWDER FROM THE LEAVES OF *SOLANUM INCANUM*

The leaves of *Solanum Incanum* were collected, cleaned with distilled water using a soft brush, and dried in the oven for 24 hours at 60 °C before being ground into powder. A 600-micrometer sieve was used for sieving to attain uniform particle sizes. Sieving increased the surface area exposed to the solvent during extraction, which led to more efficient extraction of the active compounds.

The active compounds were extracted by combining 10 grams of sieved powder in 1 litre of distilled water and stirring for at least 30 minutes. It was then filtered using a filter paper and obtained 600ml, as the filtrate, which was then used for analysis to determine the optimum contact time and dosage of the Solanum Incanum extract.

4.4.1 DETERMINATION OF THE CONTACT TIME

When it comes to disinfection, its effectiveness depends on the contact time, which is the period during which water remains in contact with the disinfectant so that harmful microbes are deactivated. (WHO, 2017).

Following research done by Somani (2011), the optimum contact time was attained first, using the time intervals of 0, 15, 30, 45, 60, 75, 90 minutes.

6 beakers were filled with raw water from Kisenyi Spring, whose initial counts of E. coli and Total Coliforms had been recorded, and then dosed with 35ml of the aqueous extract. The major aspect of contact time was to determine the minimum contact time at which microbial reduction is significantly high.

35ml was used for the Solanum Incanum Aqueous extract because it is a mid-range concentration for the recommended effective dose range of 25 - 50ml, which is commonly documented for most aqueous plant extracts used in microbial disinfection. (Suleiman et al., 2020).

4.4.1.1 E. COLI REMOVAL

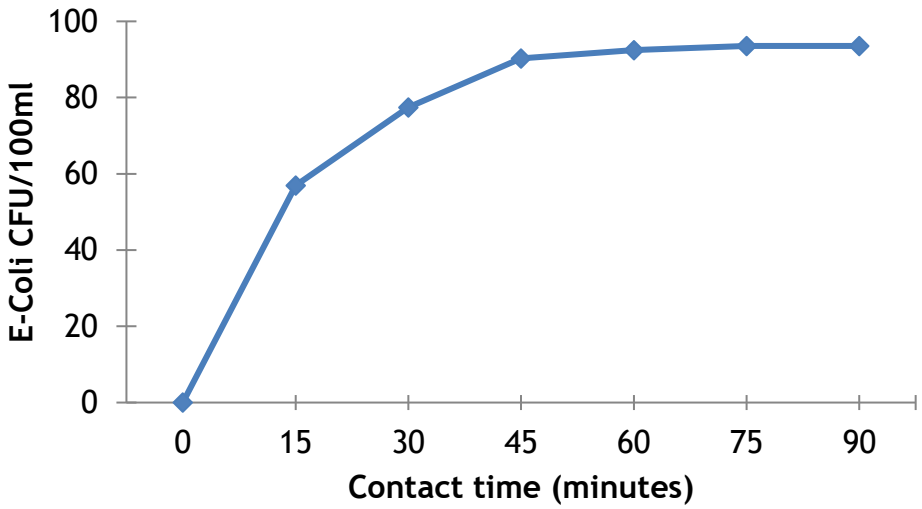


Figure 6: The percentage reduction of E. coli over contact time

Between 0 and 15 minutes, the percentage removal of E. coli was 57%, showing a high reduction and a great effectiveness of the dose. Then, between 15 and 30 minutes, the

percentage removal was 20%, which showed a gradual reduction of E. coli, raising the percentage removal to 77%. Between 30 and 45, the percentage removal of E. coli was 9%, representing a gradual reduction, which resulted in a percentage reduction to 86%. Finally, between 45 and 90 minutes, the percentage reduction of E. coli was minimal as it can be observed the graph started flattening, indicating a decrease in the effectiveness of the dose. This justified the optimum contact time as 45 minutes, as it is the time when the dose showed its significant performance.

4.4.1.2 TOTAL COLIFORM REMOVAL

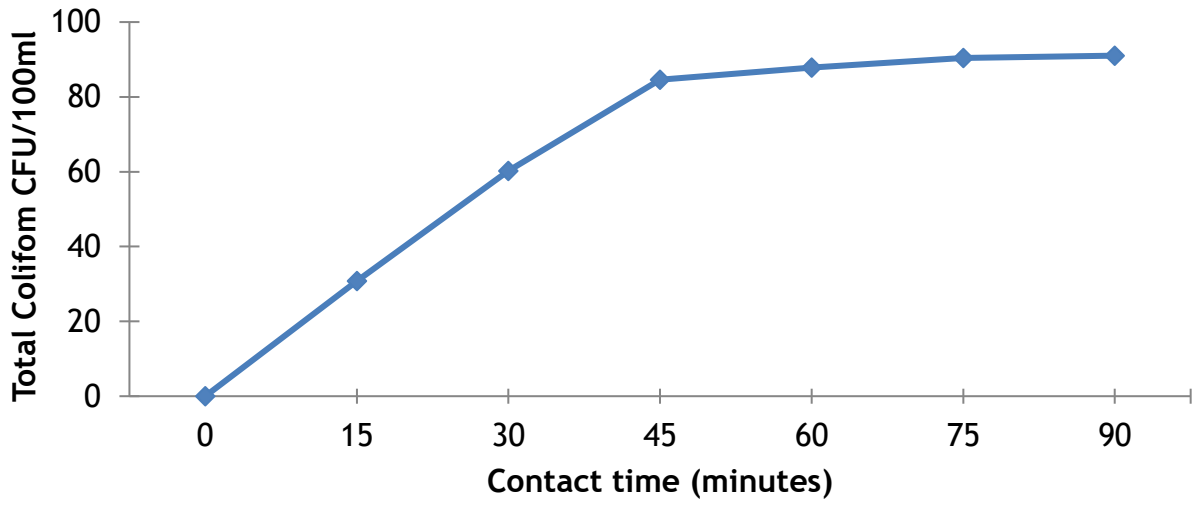


Figure 7: The percentage reduction of Total Coliforms over time

Between 0 and 15 minutes, the percentage removal of Total Coliforms was 31%, showing a high reduction. Then, between 15 and 30 minutes, the percentage removal was 29%, indicating a gradual increase to 60%. Between 30 and 45, the percentage removal was 25%, representing a gradual reduction, which resulted in a percentage reduction of 85%. Finally, between 45 and 90 minutes, the percentage reduction was minimal, suggesting

a decrease in the dose's effectiveness. This justified the optimum contact time as 45 minutes.

4.4.2 DETERMINATION OF THE OPTIMUM DOSAGE

For the aspect of determining the optimum dosage, the same amount of 1000ml, poured in 7 different beakers, was treated at the attained contact time, which is 45 minutes, with different amounts of dose of the stock solution attained from the Aqueous extract of the Solanum Incanum, as shown in the table below. The choice for dosage highly depended on the changes that were observed in the water chemistry during the trial runs of the disinfectant. The physiochemical quality of water was observed to be increasing as the bacteriological quality decreased with an increase in dosage.

4.4.2.1 TURBIDITY VARIATIONS WITH DOSAGE

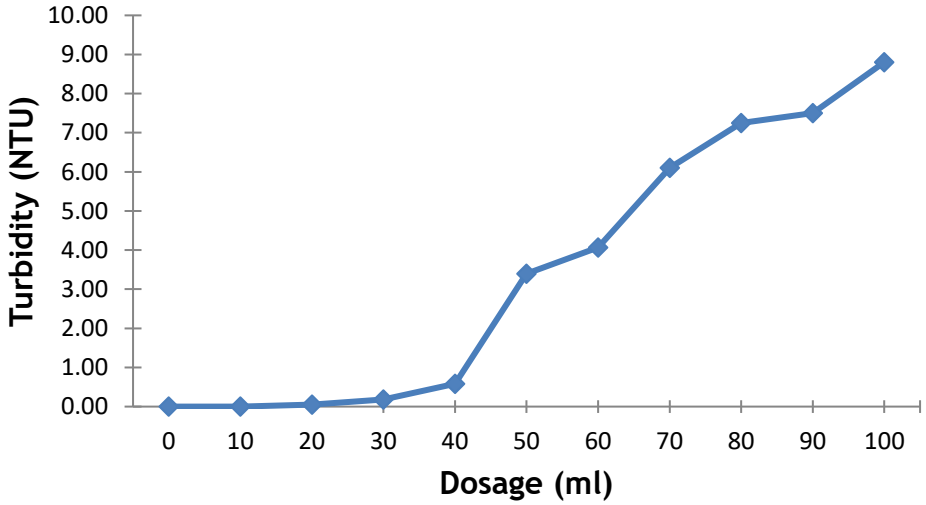


Figure 8: The variation of Turbidity with dosage.

It was observed that between 0 and 20ml, there was no significant rise in the turbidity of the treated water. Between 20 and 40ml, there was a gradual increase in the

turbidity of the treated water, of 0.05 to 0.58 NTU. Whereas between 40 and 100 ml, there was a great increase in the turbidity of the treated water, from 0.58 to 9.0 NTU.

This is due to the presence of saponins, which can form stable micelles and colloidal aggregates, which increase turbidity at higher doses. (Sivapalan, 2017). In addition to that, the extract carries microscopic leaf fibers and cell wall fragments that scatter light, thus elevating turbidity as the concentration of the dose increases. (Musyimi et al., 2012). Thus, an increase in turbidity is a natural physicochemical response to the introduction of high doses of the extract.

4.4.2.2 PH VARIATIONS WITH DOSAGE

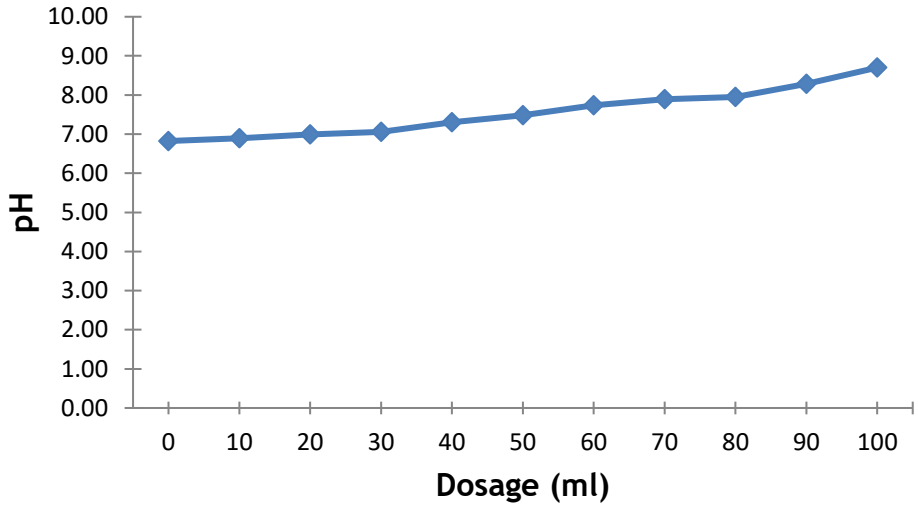


Figure 9: The variation of pH over dosage.

Based on the results shown above, it can be observed that there was a gradual increase in pH from 6.82 to 8.70 as the doses of the extract increased. This is normally attributed to the alkaline nature of the phytochemicals.

Compounds like solasonine, present in the extract, have a weak basic nitrogen atom in their structure that shifts the water pH to slightly alkaline conditions in higher concentrations. (Kilonzo & Shija, 2021).

These pH values are within the acceptable WHO standard range of 6.5 to 8.5 for dosage from 0 to 90ml, unlike the 100ml dosage, whose pH value is 8.70.

4.4.2.3 COLOR VARIATIONS WITH DOSAGE

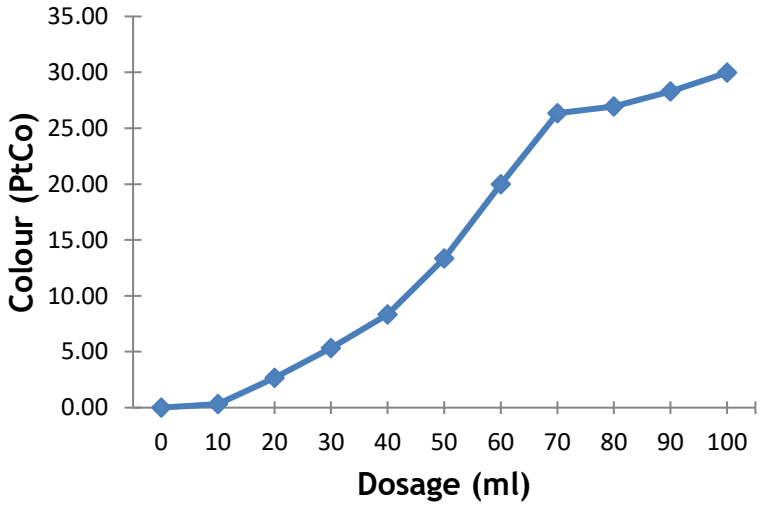


Figure 10: The variation of colour with dosage

There was a gradual increase in the colour as the dosage of the extract increased. Doses of 10, 20, 30, 40, and 50 ml had color values of 0.33, 2.67, 5.33, 8.33, and 13.33 PtCo, which are within the acceptable potable water standards of 15 PtCo.

But for doses of 60, 70, 80, 90, and 100ml, the color values were 20, 26.33, 26.93, 28.30, and 29.97 PtCo, respectively, which were above the standards. This is because the majority of the phenolic compounds in the extract dissolve in water.

The leaves contain natural pigments such as tannins and chlorophylls, which form a green brown coloration when in water. Once these molecules are introduced in water in higher volumes, they result in stronger color absorption, thus higher color readings. (Kihampa et al., 2011).

4.4.2.4 TOTAL COLIFORMS VARIATIONS WITH DOSAGE

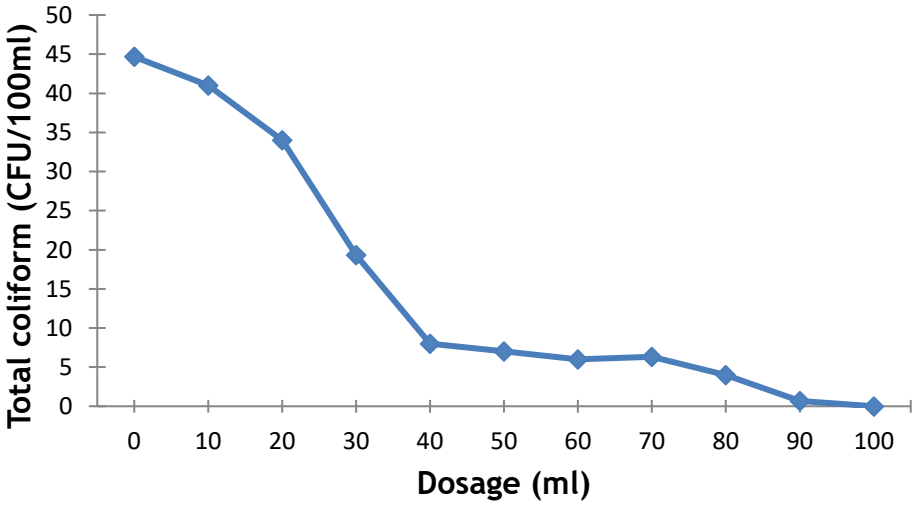


Figure 11: The variation of Total Coliforms removal with dosage.

It can be observed that Total Coliform counts reduced with an increase in dosage. This is due to the compounds such as flavonoids, tannins, among others, that exist in the

extract, which contain antimicrobial properties, enabling them to disrupt, inactivate, and destroy the microbial cell membranes, leading to their destruction. This aligns with the findings obtained by Kihampa et al. (2011) whose research report showed that the increase in the concentration of *Solanum Incanum* extract led to a significant reduction in fecal bacteria in water. Total Coliforms were completely eradicated from the raw water at a dose of 100ml.

4.4.2.5 E. COLI VARIATIONS WITH DOSAGE

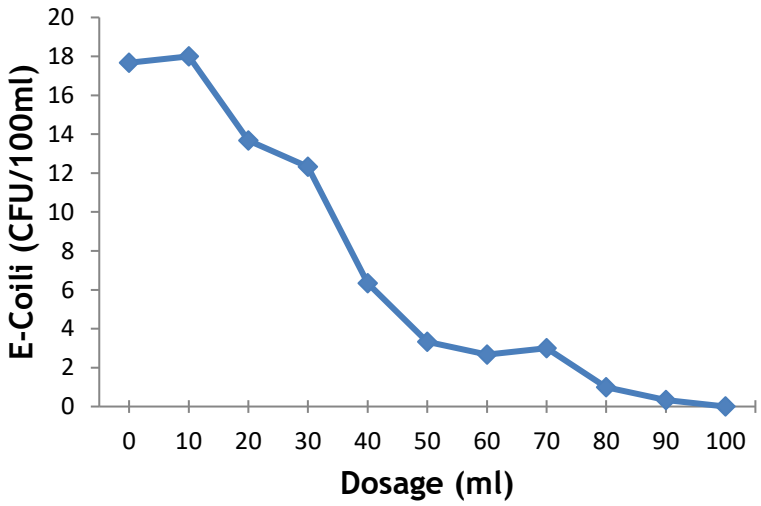


Figure 12: The variation of E. coli reduction with dosage.

It was observed that as the dose concentration increased, there was an increase in the E. coli reduction, as E. coli was eradicated from the raw water at a dose of 90ml. This is due to the presence of the active compounds, such as tannins, saponins, flavonoids, among others, which help in the disruption, inactivation, and weakening of the

microbial cells and membranes, enhancing antimicrobial activities even more at high doses. (Kilonzo & Shija, 2021).

NOTE: The optimum dosage of the Solanum Incanum extract was 40ml, at an optimum contact time of 45 minutes. This is because 40ml showed better physicochemical and bacteriological properties of the water after treatment, having turbidity of 0.58 NTU, Ph of 7.30, Apparent Color of 8.33 PtCo, E. coli of 5 CFU/100ml and Total Coliforms of 8 CFU/100ml. The bacteriological quality of the treated at this dose wasn't the best, but it was observed that the increase in dosage led to an increase in the turbidity and color of the treated water, making it undesirable for domestic use at household level.

4.5 DESIGN OF THE WATER TREATMENT AT HOUSEHOLD LEVEL IN NAMILYANGO VILLAGE

To design a suitable treatment unit, it is necessary to determine the demand for water for each household. According to the Water Supply Design Manual, the demand of water states that for low-income communities like rural areas, people consume 20 l/ca/day (Republic & Water, n.d.).

The chambers needed on the treatment unit were the disinfection unit and the storage unit. This is because the water had a turbidity of 0 NTU and a color of 0 PtCo, meaning there was no need to coagulate and sediment the water.

4.5.1 Sizing aspect

According to the Water Supply Design Manual, the required amount of water uptake by a person is 20 litres per day. Approximately 5 people per household in Namilyango (UBOS, 2024)

= 20 x 5 = 100 litres of water.

Then 10% freeboard, making it 110 litres, approximately 0.11m^3

Assuming a diameter of 0.4m (For the tanks),

V = πHr^2

0.11 = $\pi H(0.2)^2$

H = 0.8754m, approximately to 1m

Reconfirming Volume.

V = πHr^2

V = $\pi * 1(0.2)^2$

V = 0.13 m^3

(Volume for both the Disinfectant and storage tanks)

Let Velocity = 0.4 m/s, estimated the diameter of the inlet pipe, D = 32mm

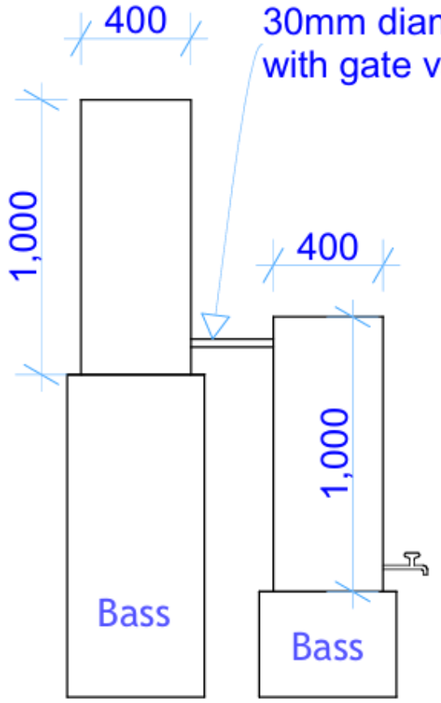
Q = A * V

Q = $\pi\,(0.016)^2 * 0.4$

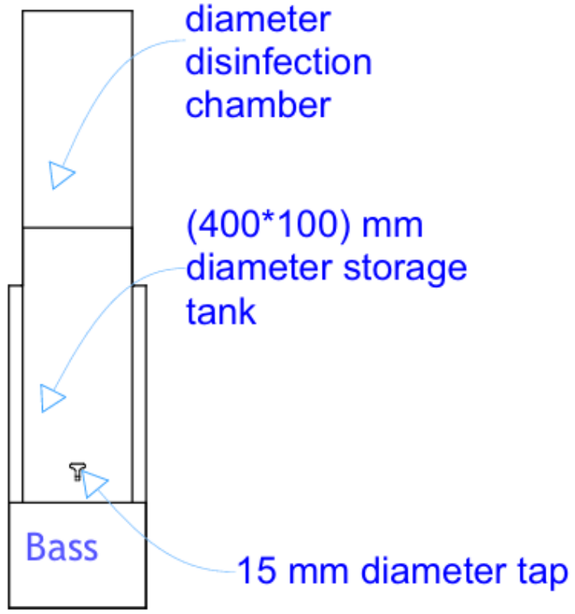
Q = 3.217 * 10^{-4} m^3/s

For the outlet tap, consider a 15mm tap.

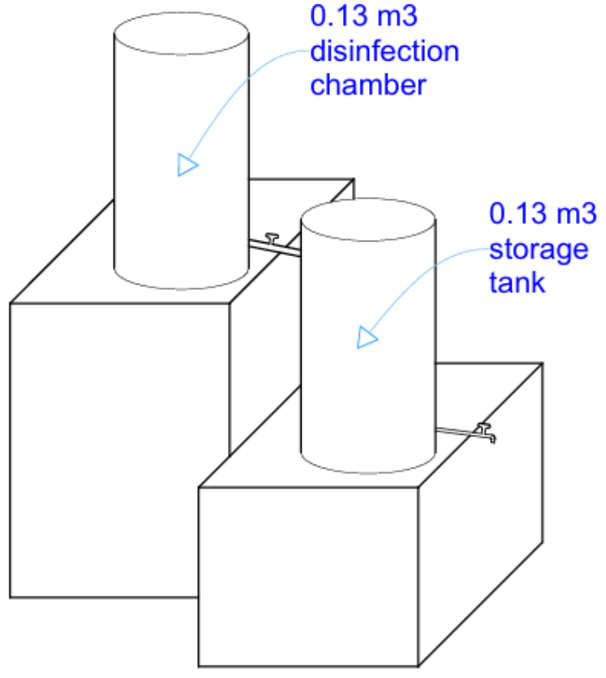
Q = $\pi\,(0.0075)^2 * 0.4$ = 7.07 * 10^{-4} m^3/s



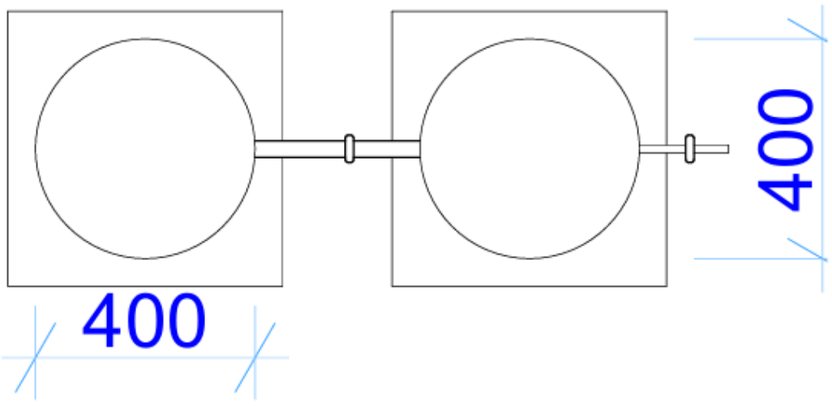
Side Elevation 1:20



Front Elevation 1:20



3D Diagram 1:25



Plan View 1:10

PROJECT;- THE USE OF SOLANUM INCANUM FOR WATER TREATMENT AT HOUSEHOLD LEVEL CASE STUDY OF NAKIJEERA SPRING	
DROWING NAME;- PLAN, FRONT AND SIDE ELEVATION, AND 3D	
DRAFTED BY;- WANABADI PETER M22B32/034 BWAMBALE WILBERFORCE M22B32/009	
SCALE;- 1:25, 1:20, 1:10	MODIFIED DATE;- 22/11/2025
PAPER SIZE;- A3	

4.6 LIMITATIONS OF USING SOLANUM INCANUM AS A NATURAL DISINFECTANT

1. Solanum Incanum adds toxicity to the water if not properly dosed. This is because it contains alkaloids, which are toxic if consumed in huge amounts or concentrations.

2. It was observed that as the dosage concentration was increased, there was an increase in the turbidity and color of the treated water. This showed that at high dosages, the water becomes undesirable for domestic use.

3. Unlike chlorine, Solanum Incanum requires a longer contact time of 45 minutes.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

1. The initial water quality of Nakyijeera Spring in Mukono District was contaminated with E. coli of 16 CFU/100ml and Total Coliforms of 48 CFU/100ml due to surface runoff, open defecation, and an unsafe water collection point.

2. The active components of *Solanum Incanum* powder were extracted using distilled water. The optimum contact time was found to be 45 minutes, and the optimum dosage was found to be 40ml with E. coli removal of 2 CFU/100ml and Total Coliform Removal of 5 CFU/100ml.

3. A water treatment system was designed, and a household water treatment prototype was made.

5.2 RECOMMENDATIONS

1. To sensitize and train communities that rely on water obtained from unprotected springs, on the safe preparations and controlled use of Solanum Incanum extract needed for water disinfection at household level in rural settings.

2. Source protection should be implemented at Nakyijeera Spring to prevent continuous contamination.

3. To enhance the bacteriological quality of the treated water, additional disinfection should be done to eliminate the microbes.

4. Additional laboratory studies and research should focus on the aspect of detoxifying the residual toxic alkaloids while preserving the plant's antimicrobial active components to ensure that the treated water remains safe for domestic use.

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APPENDICES

Figure 12: Nakyijeera Spring

Figure 13: Child fetching water

Figure 14: Solanum Incanum Plant

Figure 15: Grinding of the leaves

Figure 16: The filtrate obtained

Figure 17 : Contact time experiment

Figure 18: Water sample collection

Figure 19 Cooler box, sample carrier

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CERTIFICATE OF ANALYSIS

Certificate Number: EQL2504AU1		
Sample: Water Sample	**Sample ID No.:**	EQL/12/07/1100
Sample Description: Said to be "Spring Water"		
Party's Ref No: Nil	**Certificate Issue Date: 3rd September 2025**	
Client Name & Address: 1. Bwambale Wilberforce & Wanabadi Peter **Physical Address:** UCU, Mukono **Client's Contact** Phone No.: +256 785 195565	Job Code:	: Water Quality Test
	Sample Received On	: **29th August 2025**
	Date of Testing	: **29th August 2025**
	Completion Date	: 3rd September 2025
Sample Condition:	Liquid sample packed in a 1.5 Ltr plastic bottle	

SN	Test Parameter	Units	Test Results			Specification as per EAS 12: 2014	Test Methods
			Morning	Afternoon	Evening		
1	Turbidity	NTU	0.0	0.0	0.0	25	HACH 8195
2	pH value	-	5.4	6.2	5.7	6.5 - 8.5	US ISO 10523
3	E.Coli	Cfu/mg	16	14	15	<1	Colilert-18/APHA-9222B
4	Total Coliform	Cfu/mg	48	32	37	<1	APHA Method 9222
5	Temperature	°C	19	23.5	22.1	N/A	N/A
6	Total iron	Mg/l	0.01	0.01	0.01	0.3	US ISO 6332:1988
7	Color		0	0	0	≤15	HACH 8025

Disclaimer:

- These results relates to the sample as received and tested. Details of the sample with respect to source and representativeness is the responsibility of the client.
- This Certificate of analysis does not substitute certification of a product by the relevant authority.

Remarks: The tested sample is in compliance with physio-chemical characteristics as provided for by the National Standards for Untreated Portable Water. However, biological parameters were all beyond the established standards.

End of Report

Reviewed & Authorized by:

Eddie Ojara
Laboratory Instructor

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CERTIFICATE OF ANALYSIS

Certificate Number: EQL2522AU2

Sample: Water Sample	**Sample ID No.:** EQL/19/08/0917
Sample Description: Said to be "Spring Water"	
Party's Ref No: Nil	Certificate Issue Date: 4th August 2025
Client Name & Address: 2. Bwambale Wilberforce & Wanabadi Peter **Physical Address:** UCU, Mukono **Client's Contact** Phone No.: +256 785 195565	Job Code: : Water Quality Test Sample Received On : 3rd September 2025 Date of Testing : 3rd September 2025 Completion Date : 4th September 2025
Sample Condition:	Liquid sample packed in a 1.5 Ltr plastic bottle

SN	Test Parameter	Units	Test Results			Specification as per EAS 12: 2014	Test Methods
			Morning	Afternoon	Evening		
1	Turbidity	NTU	0.0	0.0	0.0	25	HACH 8195
2	pH value	-	6.5	6.6	6.7	6.5 - 8.5	US ISO 10523
3	E.Coli	Cfu/mg	17	11	09	<1	Colilert-18/APHA-9222B
4	Total Coliform	Cfu/mg	33	23	27	<1	APHA Method 9222
5	Temperature	°C	22.1	24.8	23.5	N/A	N/A
6	Total iron	Mg/l	0.01	0.01	0.01	0.3	US ISO 6332:1988
7	Color	PtCo	0	0	0	≤15	HACH 8025

Disclaimer:

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CERTIFICATE OF ANALYSIS

Certificate Number: EQL2522AU2

Sample: Water Sample		**Sample ID No.:**	EQL/02/09/1043
Sample Description: Said to be "Spring Water"			
Party's Ref No: Nil		**Certificate Issue Date:** 6th September 2025	
Client Name & Address: 3. Bwambale Wilberforce & Wanabadi Peter **Physical Address:** UCU, Mukono **Client's Contact** Phone No.: +256 785 195565		Job Code:	: Water Quality Test
		Sample Received On	: 4th September 2025
		Date of Testing	: 4th September 2025
		Completion Date	: 6th September 2025
Sample Condition:	Liquid sample packed in a 1.5 Ltr plastic bottle		

SN	Test Parameter	Units	Test Results			Specification as per EAS 12: 2014	Test Methods
			Morning	Afternoon	Evening		
1	Turbidity	NTU	0.0	0.0	0.0	25	HACH 8195
2	pH value	-	6.9	6.9	6.8	6.5 - 8.5	US ISO 10523
3	E.Coli	Cfu/mg	23	17	18	<1	Colilert-18/APHA-9222B
5	Total Coliform	Cfu/mg	50	26	28	<1	APHA Method 9222
5	Temperature	°C	20.7	23.3	21.5	N/A	N/A
6	Total iron	Mg/l	0.01	0.01	0.01	0.3	US ISO 6332:1988
7	Color		0	0	0	≤15	HACH 8025

Disclaimer:

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Remarks: The tested sample is in compliance with physio-chemical characteristics as provided for by the National Standards for Untreated Portable Water. However, biological parameters were all beyond the established standards.

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CERTIFICATE OF ANALYSIS

Certificate Number: EQL2513SE2

Sample: Water Sample		**Sample ID No.:** EQL/22/09/0932,1324, 1836
Sample Description: Said to be "Spring Water"		
Party's Ref No: Nil		**Certificate Issue Date:** 26th September 2025
Client Name & Address: 1. Bwambale Wilberforce & Wanabadi Peter **Physical Address:** UCU, Mukono **Client's Contact** Phone No.: +256 785 195565	**Job Code:**	: Water Quality Test
	Sample Received On	: 22nd September 2025
	Date of Testing	: 22nd September 2025
	Completion Date	: 24th September 2025
Sample Condition:	Liquid sample packed in a 1.5 Ltr plastic bottle	

SN	Test Parameter	Units	Test Results			Specification as per EAS 12: 2014	Test Methods
			Morning	Afternoon	Evening		
1	Turbidity	NTU	0.0	0.0	0.0	25	HACH 8195
2	pH value	-	6.7	6.8	6.9	6.5 - 8.5	US ISO 10523
3	E.Coli	CFU/ml	19	17	20	<1	Colilert-18/APHA-9222B
4	Total Coliform	CFU/ml	53	36	40	<1	APHA Method 9222
5	Temperature	°C	19.7	26.4	24.4	N/A	N/A
6	Total iron	Mg/l	0.01	0.01	0.01	0.3	US ISO 6332:1988
7	Color		0	0	0	≤15	HACH 8025

Disclaimer:

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Remarks: The tested sample is in compliance with physio-chemical characteristics as provided for by the National Standards for Untreated Portable Water. However, biological parameters were all beyond the established standards.

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CERTIFICATE OF ANALYSIS

Certificate Number: EQL2513SE3		
Sample: Water Sample	**Sample ID No.:**	EQL/19/08/0917
Sample Description: Said to be "Spring Water"		
Party's Ref No: Nil	Certificate Issue Date: 26th September 2025	
Client Name & Address: 2. Bwambale Wilberforce & Wanabadi Peter **Physical Address:** UCU, Mukono **Client's Contact** Phone No.: +256 785 195565	Job Code:	: Water Quality Test
	Sample Received On	: 23nd September 2025
	Date of Testing	: 23nd September 2025
	Completion Date	: 25th September 2025
Sample Condition:	Liquid sample packed in a 1.5 Ltr plastic bottle	

SN	Test Parameter	Units	Test Results			Specification as per EAS 12: 2014	Test Methods
			Morning	Afternoon	Evening		
1	Turbidity	NTU	0.0	0.0	0.0	25	HACH 8195
2	pH value	-	7.0	6.6	6.7	6.5 - 8.5	US ISO 10523
3	E.Coli	CFU/ml	21	20	22	<1	Colilert-18/APHA-9222B
4	Total Coliform	CFU/ml	40	38	43	<1	APHA Method 9222
5	Temperature	°C	21.7	26.8	24.3	N/A	N/A
6	Total iron	Mg/l	0.01	0.01	0.01	0.3	US ISO 6332:1988
7	Color	PtCo	0	0	0	≤15	HACH 8025

Disclaimer:

- These results relates to the sample as received and tested. Details of the sample with respect to source and representativeness is the responsibility of the client.
- This Certificate of analysis does not substitute certification of a product by the relevant authority.

Remarks: The tested sample is in compliance with physio-chemical characteristics as provided for by the National Standards for Untreated Portable Water. However, biological parameters were all beyond the established standards.

End of Report

Reviewed & Authorized by:

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Certificate Number: EQL2513SE4

Sample: Water Sample	**Sample ID No.:**	EQL/02/09/1043
Sample Description: Said to be "Spring Water"		
Party's Ref No: Nil	**Certificate Issue Date:** 26th September 2025	
Client Name & Address: 3. Bwambale Wilberforce & Wanabadi Peter **Physical Address:** UCU, Mukono **Client's Contact** Phone No.: +256 785 195565	Job Code:	: Water Quality Test
	Sample Received On	: 24th September 2025
	Date of Testing	: 24th September 2025
	Completion Date	: 26th September 2025
Sample Condition:	Liquid sample packed in a 1.5 Ltr plastic bottle	

SN	Test Parameter	Units	Test Results			Specification as per EAS 12: 2014	Test Methods
			Morning	Afternoon	Evening		
1	Turbidity	NTU	0.0	0.0	0.0	25	HACH 8195
2	pH value	-	6.5	6.8	6.9	6.5 - 8.5	US ISO 10523
3	E.Coli	CFU/ml	23	19	22	<1	Colilert-18/APHA-9222B
5	Total Coliform	CFU/ml	52	40	42	<1	APHA Method 9222
5	Temperature	°C	22.7	29.1	26.5	N/A	N/A
6	Total iron	Mg/l	0.01	0.01	0.01	0.3	US ISO 6332:1988
7	Color		0	0	0	≤15	HACH 8025

Disclaimer:

- These results relates to the sample as received and tested. Details of the sample with respect to source and representativeness is the responsibility of the client.
- This Certificate of analysis does not substitute certification of a product by the relevant authority.

Remarks: The tested sample is in compliance with physio-chemical characteristics as provided for by the National Standards for Untreated Portable Water. However, biological parameters were all beyond the established standards.

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Reviewed & Authorized by:

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NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: Bwambale Wilberforce M22B32/009 &

Wanabadi Peter M22B32/034

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 03 rd December , 2025.

Analysis of test results to determine the optimal dose of the extract at contact time (45 minutes) on 03rd December, 2025.

RUN 1

			Applied dosage (ml)										
SN	Parameter	Units	0	10	20	30	40	50	60	70	80	90	100
1	Turbidity	NTU	0.00	0.00	0.15	0.20	0.64	2.60	3.40	5.00	6.35	6.40	7.00
2	pH		6.80	6.84	6.92	6.97	7.24	7.52	7.84	8.03	8.23	8.42	8.60
3	Apparent colour	PtCo	0.00	0.00	2.00	6.00	10.00	12.00	18.00	24.00	24.90	26.20	26.80
4	E-coli	CFU/100ml	20	16	15	14	8	5	4	3	1	0	0
5	Total coliform	CFU/100ml	44	42	30	10	8	7	5	5	3	0	0

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
Bwambale Wilberforce M22B32/009
Wanabadi Peter M22B32/034

NATIONAL WATER AND SEWERAGE CORPORATION
04 DEC 2025
WATER QUALITY MANAGEMENT DEPT
THE CENTRAL LABORATORY

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: Bwambale Wilberforce M22B32/009 &

Wanabadi Peter M22B32/034

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 04th December, 2025.

Analysis of test results to determine the optimal dose of the extract at contact time (45 minutes) on 04th December, 2025.

RUN 3

			Applied dosage (ml)										
SN	Parameter	Units	0	10	20	30	40	50	60	70	80	90	100
1	Turbidity	NTU	0.00	0.00	0.00	0.20	0.50	4.60	5.20	6.90	8.00	8.02	10.40
2	pH		6.82	6.91	7.01	7.20	7.36	7.36	7.56	7.68	8.00	8.30	8.50
3	Apparent colour	PtCo	0.00	0.00	2.00	4.00	7.00	13.00	22.00	30.00	30.90	32.40	35.00
4	E-coli	CFU/100ml	18	20	12	11	8	2	2	3	1	0	0
5	Total coliform	CFU/100ml	44	42	40	36	8	8	6	8	5	0	0

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
Bwambale Wilberforce M22B32/009
Wanabadi Peter M22B32/034

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Date Sample Tested: 04th December , 2025.

Analysis of test results to determine the optimal dose of the extract at contact time (45 minutes) on 04th December, 2025.

RUN 2

			Applied dosage (m/l)										
SN	Parameter	Units	0	10	20	30	40	50	60	70	80	90	100
1	Turbidity	NTU	0.00	0.00	0.00	0.15	0.60	3.00	3.60	6.40	7.40	8.10	9.01
2	pH		6.85	6.94	7.04	6.99	7.30	7.56	7.80	7.96	8.00	8.33	9.00
3	Apparent colour	PtCo	0.00	1.00	4.00	6.00	8.00	15.00	20.00	25.00	25.00	26.30	28.10
4	E-coli	CFU/100ml	15	18	14	12	3	3	2	3	1	1	0
5	Total coliform	CFU/100ml	46	50	32	12	8	7	7	6	4	2	0

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
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Student: Bwambale Wilberforce M22B32/009 &

Wanabadi Peter M22B32/034

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 28th November , 2025.

Analysis of Test Results showing contact time determination at a dose of 35ml of the extract (Disinfectant) picked on 28th November 2025.

Experiment 1

		Microbial reduction CFU/100ml	
s/n	Contact time (minutes)	E-coli	Total
1	0	27	48
2	15	12	29
3	30	5	12
4	45	2	4
5	60	1	3
6	75	1	2
7	90	1	1

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
Bwambale Wilberforce M22B32/009
Wanabadi Peter M22B32/034

NATIONAL WATER AND SEWERAGE CORPORATION
29 NOV 2025
WATER QUALITY MANAGEMENT DEPT
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P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: Bwambale Wilberforce M22B32/009 &
Wanabadi Peter M22B32/034
Address: Uganda Christian University
Mukono (Uganda)
Date Sample Tested: 29th November , 2025.

Analysis of Test Results showing contact time determination at a dose of 35ml of the extract (Disinfectant) picked on 29th November 2025.

Experiment2

		Microbial reduction CFU/100ml	
s/n	Contact time (minutes)	E-coli	Total
1	0	30	63
2	15	18	45
3	30	8	34
4	45	3	12
5	60	3	9
6	75	3	8
7	90	3	8

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
Bwambale Wilberforce M22B32/009
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Wanabadi Peter M22B32/034

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 29th November , 2025.

Analysis of Test Results showing contact time determination at a dose of 35ml of the extract (Disinfectant) picked on 29th November 2025.

Experiment 3

		Microbial reduction CFU/100ml	
s/n	Contact time (minutes)	E-coli	Total
1	0	30	44
2	15	14	34
3	30	8	16
4	45	3	8
5	60	3	7
6	75	2	5
7	90	2	5

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
Bwambale Wilberforce M22B32/009
Wanabadi Peter M22B32/034

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