

AN INVESTIGATION ON THE EFFICIENCY OF LOCALLY AVAILABLE MATERIALS IN DRINKING WATER TREATMENT UNDER DIFFERENT OPERATING CONDITIONS

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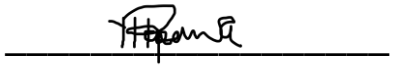
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DECLARATIONS

I Carolyn Mpaso declare that this research project represents my own work and that it has never been submitted to this institution or any other institution for any academic purpose. All sources of information have been properly acknowledged.

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I Grace Mwakhwawa declare that this research project represents my own work and that it has never been submitted to this institution or any other institution for any academic purpose. All sources of information have been properly acknowledged.

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ABSTRACT

Over the past few centuries, advances in water treatment technology have safeguarded human health against pollutants and diseases. Technologies that are affordable and appropriate for developing nations need to be taken into consideration since over a billion people worldwide lack access to clean drinking water. It is necessary to think about the sustainable functioning of these treatment procedures, taking into account easily maintained systems and materials that are readily available locally. Public health depends on having access to clean drinking water, particularly in areas with few resources. The usefulness of locally accessible materials in water treatment procedures is investigated in this work. The objective of this study was to assess the efficiency of treatment processes using locally available materials and to evaluate the impact of operating conditions on the performance of the treatment processes. In coagulation and flocculation, the capacity of locally obtained coagulants, like carica papaya seeds, hibiscus sabdarifa seeds, and alum to eliminate suspended particles was assessed. The best doses, pH ranges, and mixing speed were examined. The effectiveness of coagulation was evaluated by turbidity measurements that were obtained after running the samples on a jar test apparatus. The operating conditions that were evaluated were pH 2, 6, and 10, coagulant dose of 5ml,10ml, and 25ml, and mixing speeds of 120 RPM, 160 RPM, and 200 RPM. Adsorption and Filtration which involved the removal of organic pollutants was evaluated using corn con and bamboo biochar and GAC as adsorbents that were used as systems for filtering out particles. The operating conditions that were used in this process were the adsorbent volume of 0.5L, 1L, and 1.5L, activated biochar, and non-activated biochar. On Disinfection, water samples were disinfected using local basil, ginger, and chlorine. Chlorine was used as a reference disinfectant to compare the efficiency of locally available material. The operating conditions that were used were pH, disinfectant dose, and contact time. Data analysis for the study was done through Microsoft Excel and SPSS which involved the use of graphs and tables.

All things considered, this study sheds light on the usefulness of utilizing locally accessible resources for water purification and how they work best at specific operating conditions as the viability of employing locally sourced resources was taken into account by looking at the sustainability and Cost-Effectiveness of the materials that were used. This highlights

low-cost, long-lasting, and situation-specific community-level solutions. This research also shows a potential of positively contributing to the sustainable development goal number 6 achievement and the Malawi Vision 2063, by providing cost-effective and sustainable solutions and improving access to water for communities.

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ACRONYMS/ABBREVIATION

pH power of hydrogen

EC Electrical conductivity

FC Fecal Coliform

NTU Nephelometric turbidity unit

TDS Total dissolved solids

GAC Granular activated carbon

CFU colony forming unit

SUVA Specific Ultra-violet absorbance

ALUM aluminum sulphate

MBS Malawi bureau of standards

Temp Temperature

WHO World Health Organization

UNICEF United Children's fund

UN United Nations

Co Initial Concentration

Ceq Equilibrium concentration

MM millimeter

^{O}C degrees Celsius

Mg/l Milligram per liter

RPM Revolution per minute

HRS Hours

Min Minutes

HTH high test hypochlorite

1.1 Chapter one

1.2 INTRODUCTION

Access to clean and safe drinking water is a fundamental human right, vital for the health and well-being of individuals and communities worldwide (United Nations, 2010). However, the availability of potable water is facing increasing challenges due to factors such as population growth, urbanization, industrialization, and environmental pollution (Salehi, 2022). In response to these challenges, the field of water treatment has evolved significantly, aiming to provide effective and sustainable solutions for purifying water from various sources (Somu & Paul, 2021). This research aimed to investigate, assess, and optimize water treatment processes, particularly focused on the utilization of locally available materials and the influence of operational conditions. (Nie, Tian, Tian, & Wang, 2021). According to World Bank 2018, 83% of Malawi's population lives in rural areas, and 17 % lives in urban areas. Approximately 35% of people in rural areas and 14% in urban areas of Malawi do not have access to basic water sources which may include groundwater or water provided by the water boards, district assemblies, and NGOs (Unicef Malawi, 2020).

1.2.1 Drinking water treatment

Water treatment is a process of purifying water to a level that is safe for drinking, free of pathogens and toxic substances, good in appearance, tasteless and odorless (Ahmed & Okwadha, 2017). Drinking water treatment requires a variety of unit operations based on the water source's quality, cost, and current regulations or requirements. The price and accessibility of chemicals are just two factors that affect how much it will cost to provide the necessary level of treatment. Synthetic organic and inorganic compounds are frequently utilized in the various treatment units. These have to be imported in hard currency and are expensive in many regions. Some of the chemicals have not been regulated for use in water treatment systems because they are linked to issues with human health and the environment (Eman, Suleyman , Hamzah , Md Zahangir , & Mohd , 2010).

1.2.2 Why drinking water treatment

Water is essential for life, health, and well-being. However, many people around the world lack access to safe and clean drinking water due to various factors such as pollution, scarcity, climate change, and inadequate infrastructure. (WHO, 2023) Water treatment methods vary depending on the type and quality of the water source, the desired use of the treated water, and the available resources and technologies (Okwadha & Ahmed, 2017). For the sake of society's health and well-being, every home should have access to safe water. However, one of the biggest issues being faced by people worldwide is a lack of access to clean water and sanitary facilities. To achieve sustainable development goal number six which focuses on ensuring a clean and stable water supply and effective water sanitation for all people by 2030, Drinking water treatment must be of great priority. (UN, 2022)

1.2.3 Conventional drinking water treatment

Sedimentation

Coagulation is the physical-chemical process used to destabilize and aggregate suspended and colloidal particles in raw water, the primary objective is to form larger, settleable flocs that can be easily separated from the water. To enhance coagulation, coagulants are added to the raw water (Dayarathne, Angove, Aryal, Abuel-Naga, & Mainali, 2021).Flocculation is the gentle mixing that occurs after coagulation which allows further floc growth and aggregation. This helps to produce larger, denser flocs that can easily settle (Hinrichsen, 2019).

Settling is when water is allowed to stand in a settling basin or tank, where the flocs settle to the bottom due to gravity, and clarified water is separated from the settled solids, which are typically removed as sludge (WHO, 2011). Coagulants that are used are aluminum sulfate (Alum) ferric chloride, alga floc, and ultra floc. These coagulants have positive charge ions which neutralize the negative charge of dissolved and suspended particles and encourage aggregation.

Local Coagulants used in research.

Carica papaya seeds Cysteine protease, a positively charged protein found in, is a potential coagulant in water and wastewater treatment. Hibiscus sabdariffa seeds contain high amounts of arginine, aspartic acid, and glutamic acid, which have coagulation properties.

Filtration

After sedimentation, the filtration process follows, to remove any remaining fine particles and flocs (Treacy, 2019). Adsorption of the filter media is dependent on various factors which include the type of the filter media activator, size of the filter media and the adsorption capacity of an adsorbent is calculated using a mathematical model called Isotherm.

Filtration: it involves the removal of suspended particles in water, filter media that are used are rapid sand filter, slow sand filter, and granular activated charcoal.

The adsorption capacity of an adsorbent is calculated using a mathematical model called isotherm. Sand and GAC granular state provides a large surface area for filtration. they all have high porosity which enables them to trap impurities

Local Adsorbents used in research

Corn cob (Zea mays) biochar and bamboo (Bambusoideae) biochar. High porosity and surface area: it provides ample space for contaminant molecules to come into contact with the biochar and be adsorbed. Surface Chemistry: contains functional groups like hydroxyl, carboxyl, and carbonyl which act as microscopic hooks, attracting and holding contaminants through physical attraction, ion exchange, and hydrogen bonding. Carbon content: it has a rich carbon material that is produced through pyrolysis, converting it into a stable form that effectively absorbs organic pollutants.

Disinfection

This is the process in water treatment that ensures the removal or inactivation of harmful microorganisms, such as bacteria, viruses, and parasites, to make the water safe for consumption. Water disinfection is needed to prevent the spread of waterborne diseases (Bryd, 2023). Disinfection: involves inactivation and killing of microorganisms. The common disinfectant used is chlorine dioxide and chloramine.

They all have antimicrobial properties which inhibit microbial growth by disrupting protein synthesis and cell membranes.

Local disinfectants used in this research

Ocimum basilicum: a plant whose leaves contain essential oils like eugenol and Methyl Chavicol, which have antimicrobial properties making them suitable for disinfection.

Zingiber Officinale Roscoe (Ginger): its rhizome roots have the potential to be used as a disinfectant because of their antimicrobial properties such as phenolic and terpene.

1.3 PROBLEM STATEMENT

Access to clean and safe drinking water is a fundamental human right, as recognized by the United Nations (UN, 2019), yet millions of people in rural and semi-urban areas around the world still lack access to reliable water treatment solutions. In these regions, conventional water treatment methods often prove impractical due to limited resources and infrastructure. The challenge lies in enhancing water treatment efficiency while utilizing locally sourced materials and understanding the influence of operational variables unique to rural contexts (UN, 2019). Despite advances in water treatment technology, the scarcity of affordable, sustainable, and efficient solutions for water treatment in rural areas persists. However, there is a significant gap in research regarding the identification, selection, and utilization of these materials for water treatment (Smith , 2020). Furthermore, operational variables, such as water source quality, seasonal variations, and maintenance practices, play a crucial role in determining the effectiveness of treatment methods. These variables are often poorly understood and inadequately accounted for in existing solutions (WHO, 2018). Consequently, there is an urgent need to comprehensively analyze the influence of operational variables specific to rural and semi-urban areas on water treatment processes.

This research will help in addressing the critical gaps by investigating how locally sourced materials can be harnessed to enhance water treatment efficiency in areas with poor quality water and by systematically examining the impact of operational variables on treatment outcomes. Unavailability of water treatment chemicals of choice which are imported in hard currency (Eman, Suleyman, Hamzah, Md Zahangir, & Mohd, 2010). Little information on drinking water treatment using locally available materials in Malawi. Therefore, an investigation of the efficiency of locally available materials in drinking water treatment under different operating conditions has to be conducted. This

will not only contribute to improving access to safe drinking water but also inform the development of sustainable water treatment solutions worldwide, thereby achieving sustainable development goal 6 (UN, 2019) and Malawi Vision 2063 (Malawi Government, 2020).

1.4 MAIN AND SPECIFIC OBJECTIVES

MAIN OBJECTIVE

To optimize water treatment processes by utilizing locally available materials under various operating conditions.

SPECIFIC OBJECTIVE

1. To evaluate the effectiveness of locally available materials in different treatment processes which are sedimentation, filtration, and disinfection.

2. To assess the impact of operating conditions on the performance of the treatment processes.

- Sedimentation: pH, coagulant dose, mixing speed
- Filtration: the volume of the filter media, activated and un-activated adsorbents
- Disinfection: disinfectant dose, pH, contact time

3. To modify the water treatment process

1.5 RESEARCH QUESTIONS

- How efficient are the treatment processes using locally available materials?
- How do different operating conditions affect the performance of the treatment processes?
- What are the best operating conditions and materials for the water treatment process?

1.6 SIGNIFICANCE OF THE STUDY

- The study provides new information on the feasibility and effectiveness of using locally available resources in water treatment.

- The study will help the process optimization for individual plants to achieve performance in drinking water treatment.
- The study has contributed to the sustainable development goal 6 and Malawi Vision 2063 achievement.
- Locally optimized treatment processes can enhance community resilience by ensuring reliable clean water during emergencies (such as floods and droughts)

1.7 LIMITATIONS OF THE STUDY

The unavailability of turbidity meters led to a delay in measuring the water samples' turbidity which might have affected the results. The delayed funds and other sources gave us a short period of to do the analysis

2. Chapter two

2.1LITERATURE REVIEW

2.1.1 Global status of drinking water treatment

In 2022, a report on drinking water stated that 6 billion people use safely managed water services while 2.2 billion people remain without safely managed water services. The report shows that 1.5 billion people have access to improved water sources located within areas with a round trip of 30 minutes, 292 million people have limited improved water sources that require more than 30 minutes to collect water, 296 million people take water from unprotected wells and springs and 115 million people collect untreated surface water from lakes, ponds, rivers, and streams. (WHO, 2018).

One of the challenges faced by many rural communities in developing countries is the lack of adequate infrastructure and resources for water treatment. Many of these communities rely on surface water sources such as rivers, lakes, or ponds as their main source of water. However, these water sources are often contaminated by various pollutants such as agricultural runoff, industrial waste, and natural disasters. These pollutants can cause waterborne diseases such as diarrhoea, cholera, typhoid, dysentery, or hepatitis, which can lead to morbidity and mortality among the population. (Muryani, 2021)

The conventional water treatment methods that are commonly used in urban areas or developed countries may not be feasible for rural communities in developing countries as the populations are dispersed. This makes it difficult to implement conventional chemical water treatment systems which involve several steps. Moreover, it is extremely costly to invest in developing countries (Megersa, et al., 2016). Another reason is that these methods may require sophisticated equipment, skilled personnel, high energy consumption, or expensive chemicals that are not readily available or affordable for communities. These methods generate waste products or by-products that may pose environmental or health risks if not properly disposed or treated (Schroth, Ambulkar, & Lanfair, 2023).

However, since 2014 WHO has been testing household water treatment technologies to ensure that the users are protected from pathogens and they have been working closely

with UNICEF in several areas concerning water and health to improve water, sanitation, and hygiene. (WHO, 2018)

2.1.2 National status on drinking water treatment

Lack of access to safe water for domestic use such as drinking, cooking, bathing, and washing is a major concern in Malawi especially in peri-urban and rural areas where access to the water supply system is limited (Maoulidi, 2012). According to Water Aid, Malawi it stated that one in every three people in Malawi does not have access to clean water which is 5.6 million people (Water aid Malawi, 2023). Although 67% of Malawian households have access to drinking water, there are variations in distribution between districts and between urban and rural areas whereby 87% of urban regions have improved drinking water sources, compared to 63% of rural areas. 37% of households in rural areas spend an average of 30 minutes or more to fetch drinking water in comparison with 13% in urban areas (Unicef Malawi, 2020). Malawians in rural areas mainly depend on groundwater resources as sources of drinking water which is the same as in most developing countries and the water treated by water boards and utilities is not accessible to everyone (Mussa & Kamoto, 2023).

2.1.3 Conventional drinking water treatment processes

Water treatment is the process of removing contaminants to make the water suitable for human consumption or other purposes. Water treatment methods vary depending on the type and quality of the water source, the desired use of the treated water, and the available resources and technologies. In developing countries, where access to safe and clean drinking water is often limited or lacking, water treatment is a crucial issue for public health, environmental protection, and economic development (Muryani, 2021). These methods can remove different types of contaminants from water such as organic matter, pathogens, and chemical pollutants.

2.1.3.1 Conventional water treatment steps

1.Coagulation and flocculation

The main operating conditions in a coagulation process are coagulant type and dosage whereby the coagulant dosage is connected to the properties of the raw water and treated water or the degree of colloidal system destabilization (Mołczan, et al., 2018).

Batch reactions are used for operating process flow conditions because the Coagulant dosage is precise and not subject to disturbances caused by variations in water flow rates. Coagulation and flocculation are two important steps in drinking water treatment that help remove impurities from water. Coagulation is the process of adding chemicals to water to neutralize the negative charges on suspended particles, allowing them to stick together and form larger particles called flocs. Flocculation is the process of gently stirring the water to encourage the flocs to collide and form even larger particles that can be removed more easily. As a coagulant and flocculant aid the chemical is added following coagulant dosing to increase the size, strength, and settleability of flocs. Flocculants may be cationic, anionic, or non-ionic. They are produced with varying degrees of ionicity and in a range of molecular weights. Although these chemicals are effectively and widely used, they have drawbacks as they influence the pH of the water, increase the soluble residues, and increase the volume and metal content of the sludge. (Kalibbala, 2017)

2. Filtration

Once the flocs have settled to the bottom of the water, the clear water on top is filtered to separate additional solids from the water. During filtration, the clear water passes through filters that have different pore sizes and are made of different materials (such as sand, gravel, and charcoal). These filters remove dissolved particles and germs, such as dust, chemicals, parasites, bacteria, and viruses (Longsdon, 2018).

Water treatment plants can use a process called ultrafiltration in addition to or instead of traditional filtration. During ultrafiltration, the water goes through a filter membrane with very small pores. This filter only lets through water and other small molecules (such as salts and tiny, charged molecules). Filter media that are used include Rapid sand filter, slow sand filter, and granular activated carbon. For the filtration process to occur the

filter media used are activated using different activators. And the adsorption capacity is calculated using a mathematical model called isotherm.

Adsorption Equilibrium, or Isotherm

Adsorption equilibrium, or isotherm, is a relationship between the equilibrium liquid phase concentration and the equilibrium solid phase concentration of an adsorbent. It allows for the calculation of the adsorption capacity of the adsorbent at any given liquid-phase concentration. In experiments involving different masses of activated carbon, two different initial concentrations of the adsorbate are used, and small activated carbon sizes are used to facilitate mass transfer. The equilibrium solid-phase concentration is calculated. The isotherm plot resembles the adsorption of target compounds by activated carbon from laboratory clean water. The equilibrium relationship is not a function of the initial concentration. Equilibrium isotherm relationships can be fitted with model equations, such as the Langmuir and Freundlich models. The Langmuir model is more fundamental and has conceptual endpoints, as it asymptotically approaches a maximum solid-phase concentration at high liquid-phase concentrations and a linear equilibrium relationship at low concentration ranges. The Freundlich model can be derived theoretically from the Langmuir model assuming a distribution of adsorption site energies (Summers, Knappe, & Snoeyink, 2010).

3. Disinfection process

Disinfection, deals with the removal, deactivation, or killing of pathogenic microorganisms, it is aimed at reducing and terminating the growth and reproduction of microbes (Saha, Sonon, Turner, Hawkins, & Mickler, 2018). In this treatment stage water treatment plants may add one or more chemical disinfectants such as chlorine, chloramine, or chlorine dioxide to kill any remaining parasites, bacteria, or viruses. Microorganisms that are of great concern in drinking water are E. Coli and fecal coliform.

2.1.4 The drinking water treatment processes using locally available materials

Several studies have explored the potential of using local materials for water treatment in different contexts and settings. These materials have been shown to have various

properties that can enhance water treatment such as filtration, adsorption, coagulation, disinfection, etc. (Kumar, Poongodi, Jayakumar, & Raj, 2014).

Local coagulants that are used in the water treatment process include Moringa Oleifera, okra seeds, hibiscus sabdariffa, papaya seeds, tamarind seeds, and lablab beans. Moringa Oleifera enhances coagulation and flocculation and improves the turbidity of water (Garcia-Fayos, Arnal, Sancho, & Rodrigo, 2016). A study conducted in Ethiopia found that the addition of Moringa oleifera seed powder to water samples significantly reduced the turbidity and coliform count of the water, making it safe for drinking (Delelegn, Sahile , & Husen, 2018).

Local adsorbents that are used in drinking water treatment include sawdust, corn cob, bamboo, sand, and LECA clay. The filter media are used to adsorb colour and suspended particles from the water (Danielowska & Jabłońska, 2022).

Wood ash and other local disinfectants such as moringa, ginger, turmeric, neem leaves, and local basil work as a disinfectant in the water treatment process due to their alkaline nature and the presence of certain chemicals that can help kill or inhibit the growth of microorganisms (Abelenda, et al., 2020). Wood ash is alkaline, and primarily composed of calcium carbonate. When added to water, it increases the pH, making the water more alkaline. The elevated pH creates an environment that is less conducive to the survival and growth of many disease-causing microorganisms, including bacteria and viruses (Msagati, Adeeyo, Edokpayi, Alabi, & Odiyo, 2021). Therefore, there is a need for alternative water treatment methods that use locally available resources and cheap materials to improve the quality and safety of surface water sources in rural communities in developing countries (WHO, 2018). They should also be cost-effective, easy to use and maintain, environmentally friendly, and culturally acceptable. (CDC, 2022).

2.1.5 Literature Review Summary

However, there are still some gaps or limitations in the current literature on water treatment using local materials. For instance:

- Most of the studies have evaluated the performance of single materials rather than combinations or mixtures of different materials.
- Most of the studies have measured only one or a few parameters of water quality rather than comprehensive indicators of water quality.
- Most of the studies have neglected the economic aspects such as costs or benefits of using local materials for water treatment.

3. Chapter three

3.1 METHODOLOGY

3.1.1Research design

The research used a quantitative research method, where water treatment efficiency utilizing locally sourced materials was analyzed under different operational variables. Different water quality parameters were measured and optimized using different materials.

3.1.2 Methods and Materials

The following materials were used in the study: spectrophotometer, membrane filtration technique, 20L bucket, HT 1000, pH meter, multimeter, sampling bottles,70% ethanol, 10 % phosphoric acid, lauryl sulfate broth, sieves, oven, incubator, blender, hotplate, motor and pestle Carica papaya, hibiscus sabdarifa, aluminum sulfate, corn cob (Zea mays), bamboo, Granular activated charcoal, local basil, Ginger (zingiber officinale) and Chlorine.

3.1.2.1 Sedimentation

Sedimentation was divided into two parts which included coagulation and flocculation.

An investigation of the sedimentation process in drinking water treatment was done by using different natural coagulants which include hibiscus sabdariffa seeds, Carica papaya seeds, and alum. A chemical coagulant that was used in this investigation is alum as a reference coagulant.

The chosen coagulants were tested on how they aided coagulation at different operating conditions which include pH, coagulant dose, and mixing speed using the batch coagulation experiment.

1. **Preparation of coagulant from Hibiscus Sabdariffa seeds.**

Hibiscus Sabdariffa seeds were bought from Lilongwe, from agro-dealers. The seeds were washed with water and dried using sunlight for 5 hours. The dried seeds were then crushed into powder form using a motor and pestle and then sieved for particle uniformity. 5 g of seed powder was mixed with 100 ml of distilled water as a solvent to

extract its coagulant agent. The extraction was done by using a household food blender for 2 minutes. The coagulant was filtered through muslin cloth to remove impurities and used in the subsequent jar test. This was done to prevent microbial decomposition of organic compounds present in the coagulant (YONG & ISMAIL, 2016).

NB: the coagulant was prepared and used within 48 hours for optimum performance.

2. Papaya carica seeds preparation for coagulation

Papaya seeds contain a group of proteins known as enzymes. These enzymes can react with other substances in the water, causing particles to clump together. Seeds were collected from the papaya fruit that were bought at Goliati market. The seeds were prepared by initially washing and removing the surface membrane layer using a cloth. The seeds were deshelled and then left to dry in an oven for 24 h at 50◦C. The dried seeds were crushed to a fine powder and sieved for particle uniformity (Amran, et al., 2012).For the bio-coagulant, particles smaller than 0.4 mm were used.

500 mg of deshelled Carica papaya seeds powder was mixed with 500 mL of distilled water. The extraction was done by using a household food blender for 2 minutes. The extracted deshelled Carica papaya seed was filtered to separate the solid from the liquid. The filtered solution was kept a room temperature to maintain its properties and labeled as a stock coagulant. Stock

3. Aluminum sulfate preparation for coagulation

It is also known as aluminum sulfate and is a commonly used coagulant in water treatment processes. 80 grams of aluminum sulfate crystals were weighed and transferred into a clean, dry beaker and then 1000 milliliters of distilled water were added into the glass beaker. A glass rod was used to stir the mixture until the aluminum sulfate crystals were completely dissolved (Malik, 2018).

The Batch coagulation experiment

Every coagulant was tested in a batch using the jar test apparatus, a jar test apparatus accommodates a series of beakers together and contains spindle steel paddles.

Temperature Range of the jar test

The temperature during jar testing should ideally match the ambient temperature of the water being treated. In most cases, room temperature (around 20°C to 25°C) is suitable. Extreme temperatures (too hot or too cold) may affect chemical reactions and floc formation.

Voltage Supply to jar test

The jar test does not directly involve voltage supply. It primarily relies on mechanical stirring. The stirring mechanism (usually a magnetic stirrer or mechanical paddle) operates independently of voltage. Ensure that the stirring equipment is functioning correctly and consistently.



Figure 0-1 jar test setup

1. Initial parameters of the raw water were measured which included turbidity, pH, TDS, EC, FC, Temperature, and SUVA 254.
2. 1000ml of the raw water sample was poured into each beaker
3. Different concentrations of the coagulant were added to each beaker and the beakers were labeled.

4. The jar apparatus was switched on to stir the solutions for a period of 2min for the flash mix at a rate of 120-200 rpm and slowly at 30 rpm for 10 minutes
5. After the sample was stirred it was left for 30 minutes to settle and then the final turbidity was measured.
6. Final parameters of the treated water were measured which include turbidity, pH, TDS, EC, Temperature, FC, and SUVA254

Sedimentation experimental design

Parameters: NTU, pH, TDS, EC, Temperature, FC, and SUVA-UV 254

Floc mixing speed: 30 RPM (10 minutes)

Settling time: 30 minutes

Treatment	Operating Conditions								
	pH			Coagulant Dose (mg/L)			Flash mixing speed 2min (RPM)		
	2	7	10	5	15	25	120	160	200
Alum									
Hibiscus sabdariffa									
Papaya Carica									

Table 1 above shows an experimental design for sedimentation

3.1.2.2 Filtration methods and materials

Adsorbent to be used, biochar, maize corn cob, and commercial GAC

Biochar is a charcoal-like substance produced by the thermal decomposition of organic materials from agriculture and forestry in the absence of oxygen. (Quispe, Campos, Masek, & Bogush, 2022)Biochar: Biochar is a carbon-rich material produced by the pyrolysis of biomass. It can be used as an adsorbent for removing organic and inorganic contaminants from water (Wang, et al., 2019). To use biochar for water treatment, the following steps will be used:

A. Preparation of Biochar from bamboo

1. The biochar was prepared from bamboo by cutting it into small pieces.

2. Pyrolysis was done by heating the bamboo at a temperature range of 300°C to 500°C.
3. The biochar was cooled using water and then sun-dried and it was crushed into desirable sizes.
4. The biochar was activated by a chemical method using a 10% concentration of phosphoric acid to enhance the adsorption capacity of the biochar.
5. The acidity was reduced by cleansing it with tap water until its PH reached 7 and then washed with distilled water.
6. The biochar was set in a fixed-bed column as a membrane filter under different volumes of 0.5L, 1L, and 1.5 L.
7. Initial parameters of the sample were measured which are: NTU, TDS, pH, Temperature, FC, and EC.
8. 1000ml of the sample was filtered.
9. The final parameters of the sample were measured.

B. Preparation of Biochar from corn cob

Corn cob is an agricultural waste material that can be used as a low-cost adsorbent for water treatment. The corncob utilized in this investigation was obtained from Goliath, Thyolo Malawi. The recovered adsorbent was rinsed multiple times with distilled water to remove earthy debris, soil, and exterior dust particles. The biochar was prepared from corn cob by cutting it into small pieces. Pyrolysis was done by heating the corn cob at a temperature range of 300°C to 500°C. The biochar was cooled using water and sun-dried then it was crushed into desirable sizes. The biochar was activated by a chemical method using phosphoric acid to enhance the adsorption capacity of the biochar. The acidity was reduced by cleansing it with tap water until its PH reached 7 and then washed with distilled water (Chaudhari & Patkar, 2022).

Procedures

1. The biochar was set in a fixed-bed column as a membrane filter.

2. Initial parameters of the sample were measured which are: NTU, TSS, TDS, pH, Temperature, EC, and FC.

3. 1000ml of the sample was filtered.

4. The final parameters of the sample were measured which are NTU, TSS, TDS, pH, Temperature, EC, and FC.

C. **Granular activated carbon** (GAC) is a widely used adsorbent for water treatment. It can remove various contaminants from water, such as organic compounds, volatile organic compounds (VOCs), synthetic organic compounds (SOCs), disinfection byproducts (DBPs), taste and odour compounds, and some metals.
To use GAC for water treatment the following steps were followed.

1. Activated Charcoal was bought from Lilongwe
2. The GAC was activated using the physical method by steam at 800 to 1000°C.
3. The granular activated carbon was set in a fixed-bed column as a membrane filter.
4. Initial parameters of the sample were measured which are: NTU, TSS, TDS, pH, Temperature, FC, and EC.
5. 1000ml of the sample was filtered.
6. The final parameters of the sample were measured.

Below is a figure showing the experimental setup and a table of activators to be used

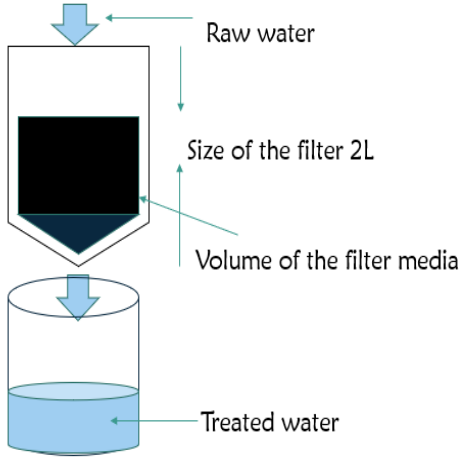


Figure 0-2 filtration setup design



Figure 0-3 above shows the experimental setup of a filter media

Adsorbent	adsorbent activator
Activated Charcoal	Steam 800 to 1000 Degree Celsius
Corn Cob Biochar	10% Phosphoric acid
Bamboo Biochar	10% phosphoric acid

Table 2 above shows adsorbents and their activators

Filtration experimental design

TREATMENT	OPERATING CONDITIONS FACTOR							
	pH			Volume of the filter media (L)			Size of the adsorbent	
	2	6	10	0.5	1.0	1.5	Granules	
Commercial GAC								
Corn cob								
Biochar								

Table 3 above shows a filtration Experimental Design

Parameters: NTU, TSS, TDS, pH, Temp, EC

Table 4 below are the isotherm (adsorption equilibrium) results

Initial Concentration, C_o	DOSE (mg/l)	C_{eq} (mg/l)	q_{eq} (mg/g AC)
GAC			
Biochar			
Corn cob			

$$qeq = (Co - Ceq) \times V/m = (Co - Ceq) / dose$$

Adsorption capacity

1. Procedures

A known mass of sample (usually an adsorbent material) is added to a fixed volume of liquid with a specific initial concentration. The liquid is mixed, either using a stirrer or by agitating the entire cell, to ensure uniform distribution. Over time, the concentration of the adsorbate (the substance being adsorbed) in the liquid is monitored until equilibrium is reached.

2. Purpose:

Equilibrium Information: Batch adsorption experiments provide data on how much adsorbate can be removed by the adsorbent at equilibrium. Kinetic Information: They also yield insights into the rate of adsorption—how quickly the process occurs.

3. Variations:

To obtain an adsorption isotherm, the experiment is repeated by varying either the amount of solid (adsorbent) the initial concentration of the solution, or both.

Two relevant cases on variations:

a. Physisorption in Porous Beads: Here, internal mass transfer is governed by diffusion within the porous structure of the adsorbent.
b. Chemisorption (Shrinking Core Mechanism): In this case, more complex kinetic schemes can be developed, but they are system-dependent and beyond the scope of this explanation.

The batch adsorption experiments help us understand how adsorbents interact with liquids and provide valuable information for various applications, from environmental remediation to industrial processes.

3.1.2.3 Disinfection

Batch experiment using a jar test apparatus

Using ocimum Basilicum (local basil), Zingiber Officinale Roscoe (Ginger), and chlorine

A. **Ocimum basilicum:** is a plant that naturally grows in warm weather conditions and it thrives in well-drained fertile soil with plenty of sunlight. Basil leaves contain essential oils like eugoniol, which have antimicrobial properties making them suitable for disinfection.

Preparation

1. The Ocimum Basilicum was uprooted from the fields
2. The leaves were plucked from the plant and then cleaned with tap water and subsequently with distilled water 3 times
3. The leaves were pre-weighed and then crushed with a mortar and pestle to increase its surface area and release its active compounds
4. Prepare Ethanol Solution

   - Food-grade ethanol was obtained (such as ethanol with at least 70% alcohol content).
   - The chopped basil leaves were mixed with the ethanol in a clean glass container. The ratio can vary, but a common proportion is about 1 part basil leaves to 5 parts ethanol.

5. Extraction Process

   - The container was sealed and was left to sit for several days (usually around 3 to 7 days) at room temperature.
   - The container was gently Shaken once a day to aid in the extraction process.

6. Filter the Solution:

   - After the extraction period, the solution was strained through a fine mesh to remove the solid basil particles.
   - The Ocimum Basilicum solution was ready for use.

7. Dilution and Application

- The solution was diluted for disinfection in drinking water and was diluted appropriately.
- Add a small amount (a few drops) of the basil-infused ethanol to a larger volume of water.

8. The extract was weighed gravimetrically to find the dose to be used for disinfection.

9. The mixture was stirred well to ensure even distribution.

Disinfection

1. The initial parameters of the sample were measured which are pH, Temperature, and fecal coliform.
2. The Ocimum Basilicum extract was added to a 1000 ml water sample.
3. The mixture was efficiently mixed using a jar test apparatus at 20 RPM for 1 to 3 minutes.
4. The disinfected sample parameters were tested again to find the effect of the disinfectant on the water sample at different contact times.

B. **Zingiber Officinale Roscoe (Ginger):** is a flowering plant that belongs to the Zingiberaceae family and its rhizome roots are used for a various purpose. It used as a disinfectant because of its potential antimicrobial properties such as phenolic and terpene (Mane, Bhandari, & Ranade, 2021).

Preparation

1. The Ginger was cleaned with tap water and subsequently with distilled water for 3 times
2. The Ginger was pre-weighed and then peeled and crushed with a mortar and pestle to release its active compounds

5. Prepare Ethanol Solution

- Food-grade ethanol was obtained (such as ethanol with at least 70% alcohol content).

- The chopped ginger roots were mixed with the ethanol in a clean glass container. The ratio can vary, but a common proportion is about 1 part basil leaves to 5 parts ethanol.

5. Extraction Process

- The container was sealed and was left to sit for several days (usually around 3 to 7 days) at room temperature.
- The container is gently Shaken once a day to aid in the extraction process.

6. Filter the Solution:

- After the extraction period, the solution was strained through a fine mesh to remove the solid ginger particles.
- The ginger solution was ready for use.

7. Dilution and Application

- The solution was diluted for disinfection in drinking water and was diluted appropriately.
- Add a small amount (a few drops) of the ginger-infused ethanol to a larger volume of water.

8.The extract was weighed gravimetrically to find the dose to be used for disinfection.

Disinfection

1. The initial parameters of the sample were measured which are pH, Temperature, and fecal coliform.
2. The ginger extract was added to the 1000ml water sample.
3. The mixture was efficiently mixed using a jar test apparatus at 20 RPM for 1 to 3 minutes.
4. The disinfected sample parameters were tested again to find the effect of the disinfectant on the water sample at different contact times.

C. **Chlorine**

Granular Chlorine Preparation

- 15 grams of HTH was added to 1 liter of water.
- The mixture was stirred until it dissolved to create a chlorine solution with an approximate concentration of 500 milligrams per liter.

Disinfection using granular chlorine.

1. The chlorine was weighed gravimetrically to find the dose to be used for disinfection
2. The initial parameters of the sample were measured which are pH, Temperature, and fecal coliform
3. The chlorine was added to the 1000ml water sample
4. The mixture was efficiently mixed using a jar test apparatus at 20 RPM for 1 to 3 minutes
5. The disinfected sample parameters were tested again to find the effect of the disinfectant on the water sample at different contact times

Parameters: pH, Temp, and fecal coliform

TREATMENT	OPERATING CONDITIONS FACTOR		
	pH	Disinfectant Dose(mg\l)	Contact time (minutes)
	2 6 10	10 20 30	10 20 30
Chlorine			
Ginger			
Local basil			

Table 5 Above shows disinfectants under different operating condition

4. Chapter four

4.1 HYPOTHESIS

- The project aimed to help identify new cost-effective methods and materials for drinking water treatment.
- The project helped in coming up with optimal conditions for water treatment at different stages to achieve better results.
- The project helped to come up with a more efficient and effective method for drinking water treatment using locally available materials.
- clearer appearance of water as many microorganisms and impurities will have settled or been inactivated by the disinfectant to be used.
- The results after treatment were to meet the WHO and MBS drinking water quality standards

4.2 RESULTS AND DISCUSSIONS

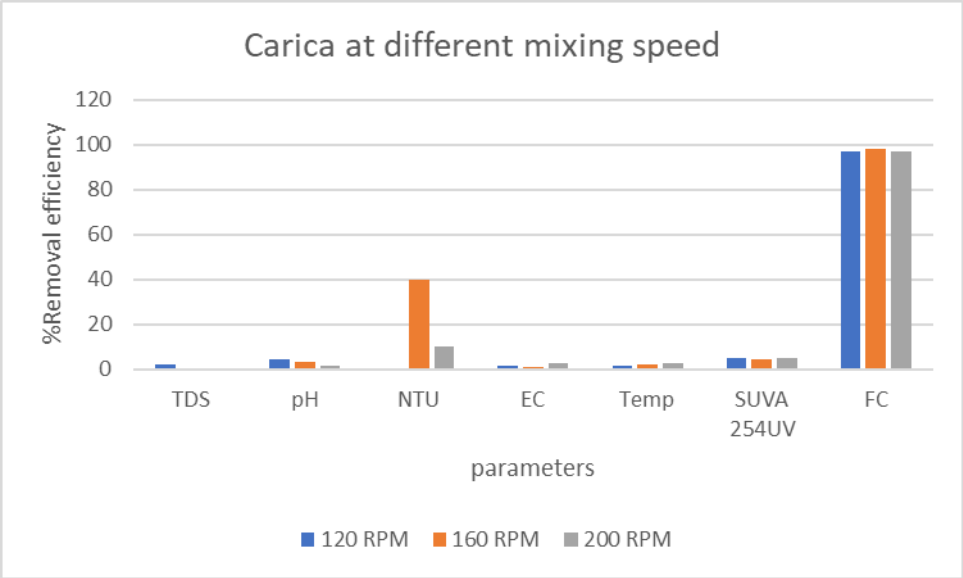
4.2.1 COAGULATION

4.2.1.1 Mixing speed operating condition

Mixing speed		120 RPM			160 RPM			200 RPM		
Type of coagulant	Parameter	initial	final	Treatment %	initial	final	Treatment %	initial	final	Treatment %
Papaya Carica	TDS	290	284	2.068966	290	289	0.344828	290	290	0
	pH	7.96	8.29	4.145729	7.96	8.23	3.39196	7.96	8.09	1.633166
	NTU	20	20	0	20	12	40	20	18	10
	EC	568	577	1.584507	568	573	0.880282	568	584	2.816901
	Temp	26.8	26.4	1.492537	26.8	26.2	2.238806	26.8	26.1	2.61194
	SUVA 254UV	1.01	0.96	4.950495	1.01	1.052083	4.166667	1.01	0.96	4.950495
	FC	1000	28	97.2	1000	20	98	1000	31	96.9
Hibiscus sabdariffa	TDS	290	287	1.034483	290	292	0.689655	290	290	0
	pH	7.96	8.22	3.266332	7.96	8.18	2.763819	7.96	8.04	1.005025
	NTU	20	16	20	20	15	25	20	20	0
	EC	568	590	3.873239	568	585	2.992958	568	596	4.929577
	Temp	26.8	26.3	1.865672	26.8	26.2	2.238806	26.8	26.2	2.238806
	SUVA 254UV	1.01	1	0.990099	1.01	1.09	7.920792	1.01	1.01	0
	FC	1000	1000	0	1000	132	86.8	1000	34	96.6
Aluminum Sulphate	TDS	290	284	2.068966	290	292	0.689655	290	287	1.034483
	pH	7.96	8.15	2.386935	7.96	8.2	3.015075	7.96	8.05	1.130653
	NTU	20	16	20	20	11	45	20	14	30
	EC	568	587	3.34507	568	586	3.169014	568	588	3.521127
	Temp	26.8	26.3	1.865672	26.8	26.3	1.865672	26.8	26.1	2.61194
	SUVA 254UV	1.01	1	0.990099	1.01	0.99	1.980198	1.01	0.98	2.970297
	FC	1000	200	80	1000	142	85.8	1000	30	97

Table 6 Above shows different Coagulants at different mixing speed

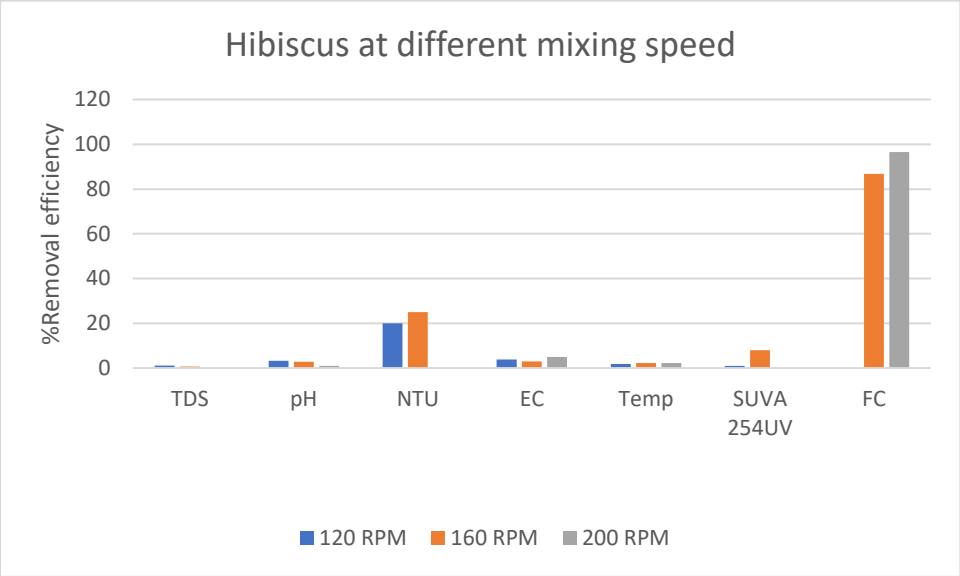
4.2.1.1.1 Carica papaya



The results indicate that at 120RPM carica had 0% removal efficiency of NTU which means there was no treatment since there was no change in the turbidity. The low speed (120 RPM) might not provide sufficient mixing, leading to incomplete reactions or poor dispersion of chemicals.

At the mixing speed of 160 RPM, the results indicate that there was 40% removal efficiency. This shows that 160 RPM gives better results of NTU removal as a mixing speed since it strikes a balance between efficient mixing and manageable shear stress. The high mixing speed (200 RPM) can cause excessive shear stress, potentially damaging sensitive compounds or altering their behavior, this is why its removal efficiency is at 10%.

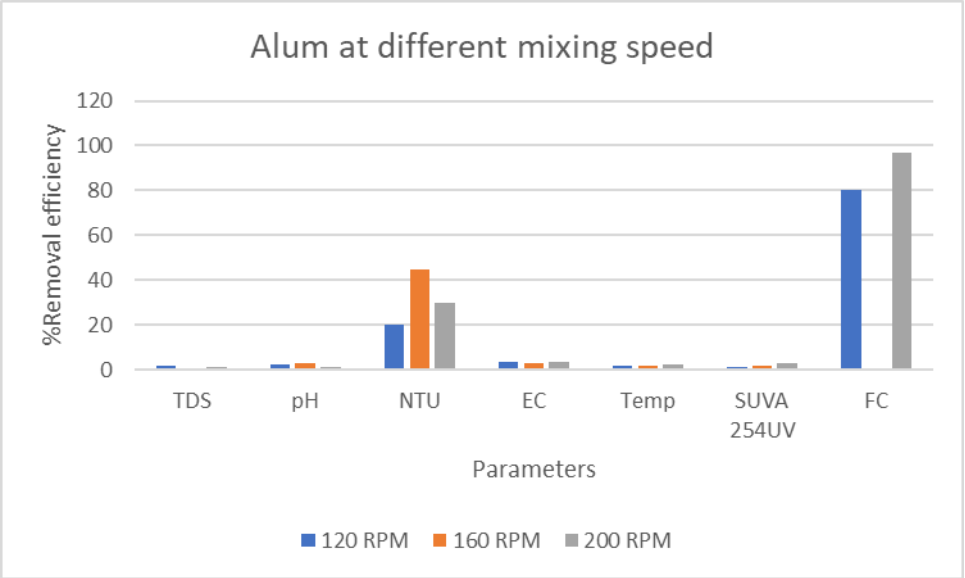
4.2.1.1.2 Hibiscus sabdarifa



The results also indicate that at 120 RPM hibiscus had 20% removal efficiency of NTU which means their minimal treatment. The low speed (120 RPM) might not provide sufficient mixing, leading to incomplete reactions or poor dispersion of chemicals.

At the mixing speed of 160 RPM, the results indicate that there was 25% removal efficiency. This shows that 160 RPM gives better results of NTU removal as a mixing speed increases since it strikes a balance between efficient mixing and manageable shear stress. The high mixing speed (200 RPM) can cause excessive shear stress, potentially damaging sensitive compounds or altering their behavior, this is why its removal efficiency is at 0%.

4.2.1.1.3 Aluminium sulphate



At 120 RPM alum has the NTU 20% removal efficiency is relatively low. This could be due to inadequate flocculation. At lower mixing speeds, the alum particles may not form large and stable flocs, leading to less effective turbidity removal. Increasing the mixing speed enhances flocculation, resulting in better removal efficiency. The 45% removal efficiency at 160 RPM likely results from improved flocculation. At this mixing speed, the alum particles form larger and more stable flocs, leading to better turbidity removal compared to 120 RPM. Higher mixing speeds enhance the collision and aggregation of particles, optimizing the coagulation process. 200 RPM shows lower efficiency than 160 RPM, so it's essential to consider the trade-offs and system-specific factors. Adjusting the mixing speed within an optimal range can enhance alum's performance. As the mixing speed increases, the NTU removal efficiency improves significantly.

Correlations

		mixing speed (RPM)	Turbidity (NTU)
mixing speed (RPM)	Pearson Correlation	1	.000
	Sig. (2-tailed)		1.000
	N	9	9
Turbidity (NTU)	Pearson Correlation	.000	1
	Sig. (2-tailed)	1.000	
	N	9	9

Table 7 Above shows correlation between mixing speed and turbidity

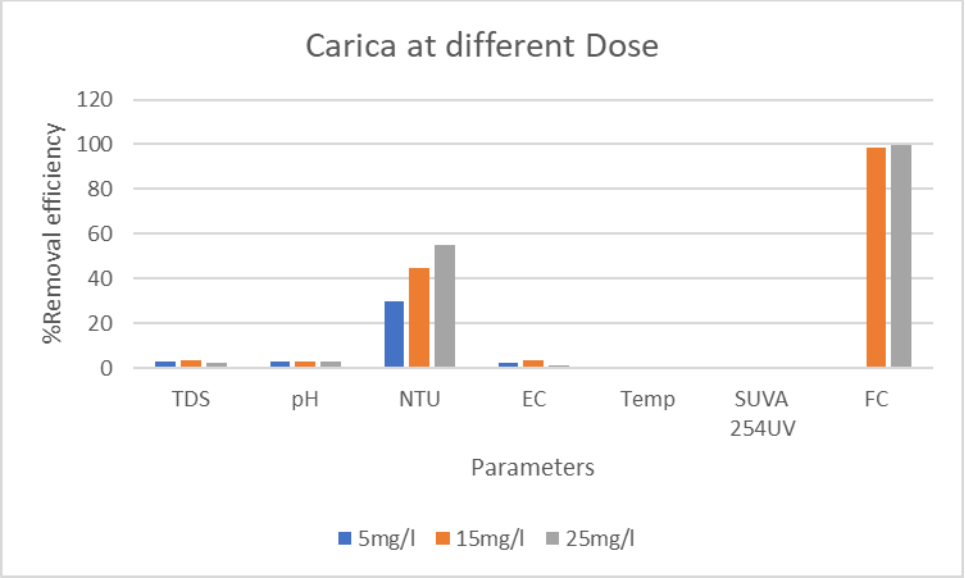
The Pearson correlation coefficient between mixing speed (RPM) and turbidity (NTU) is which means that we fail to reject the null hypothesis that there is no significant linear relationship between mixing speed and turbidity.

4.2.1.2Coagulation Dose operating condition

Dose		5 mg/L			15mg/L			25 mg/L		
Type of coagulant	Parameter	initial	final	Treatment %	initial	final	Treatment %	initial	final	Treatment %
Papaya Carica	TDS	290	281	3.103448	290	279	3.793103	290	283	2.413793
	pH	7.96	8.18	2.763819	7.96	8.2	3.01508	7.96	8.22	3.26633
	NTU	20	14	30	20	11	45	20	9	55
	EC	568	554	2.464789	568	548	3.521127	568	560	1.408451
	Temp	26.8	26.9	0.373134	26.8	26.8	0	26.8	26.7	0.373134
	SUVA 254UV	1.01	1.01	0	1.01	1	0.990099	1.01	1	0.990099
	FC	1000	1000	0	1000	12	98.8	1000	3	99.7
Hibiscus Sabdariffa	TDS	290	287	1.034483	290	284	2.068966	290	282	2.758621
	pH	7.96	7.94	0.251256	7.96	7.96	0	7.96	7.85	1.38191
	NTU	20	7	65	20	13	35	20	25	25
	EC	568	575	1.232394	568	574	1.056338	568	570	0.35211
	Temp	26.8	279	941.0448	26.8	26.7	0.373134	26.8	27	0.74627
	SUVA 254UV	1.01	1	0.990099	1.01	1.01	0	1.01	1	0.990099
	FC	1000	1000	0	1000	8	99.2	1000	12	98.8
Aluminum sulphate	TDS	290	281	3.103448	290	278	4.137931	290	276	4.827586
	pH	7.96	8.21	3.140704	7.96	8.13	2.135678	7.96	8.12	-2.01005
	NTU	20	17	15	20	7	65	20	4	80
	EC	568	570	0.352113	568	568	0	568	563	0.880282
	Temp	26.8	26.7	0.373134	26.8	26.7	0.373134	26.8	26.9	-0.37313
	SUVA 254UV	1.01	1.09	7.920792	1.01	1	0.990099	1.01	1	0.990099
	FC	1000	56	94.4	1000	87	91.3	1000	95	90.5

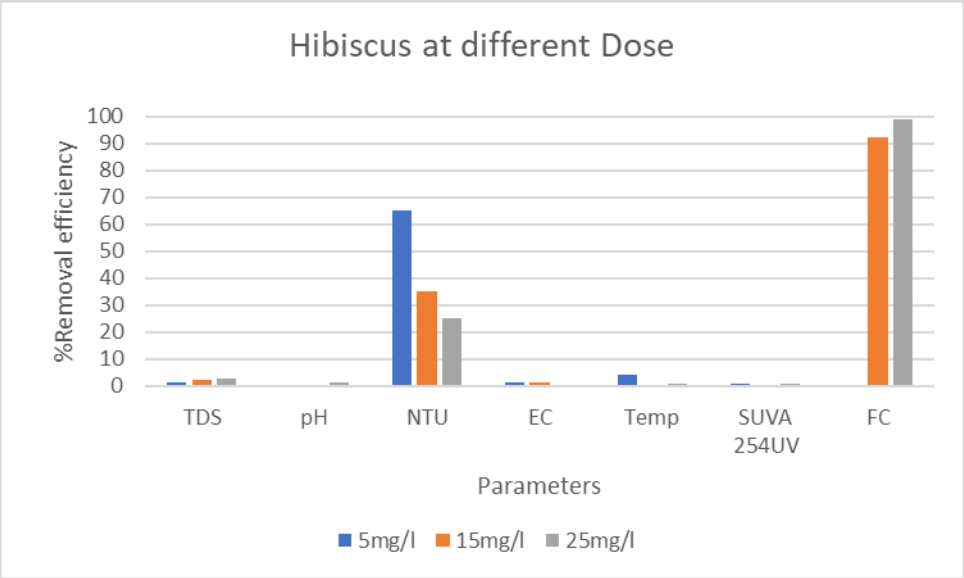
Table 8 Above shows different coagulants and their dose

4.2.1.2.1 Carica Papaya



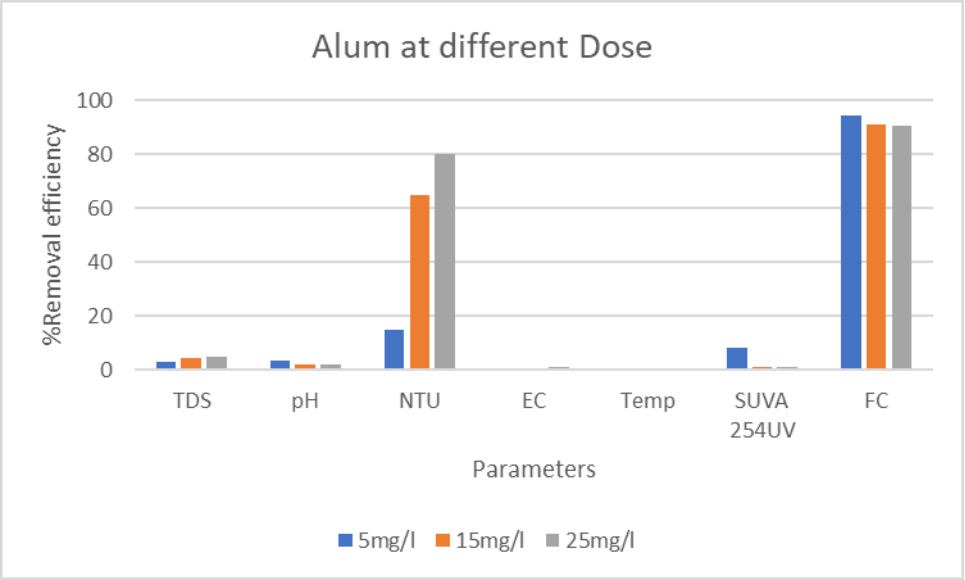
The highest removal efficiency is observed in the FC and NTU parameters with the 25 mg/l dose. The removal efficiency varies with the concentration of Carica. An increase in the dose is causing an increase in the removal efficiency of turbidity and fecal coliform. This is due to collision frequency this is where coagulation relies on collision between particles in solution and molecules in the coagulant. Therefore, an increase in the dose also increases the number of molecules available to collide with suspended particles (Sun, Zhou, Chiang, & Shah, 2019). Another reason was due to bridging and sweeping, whereby coagulants work by forming long charge polymer chains that can bridge between multiple suspended particles. This might have caused coagulant to form larger flocs at higher doses, therefore, enhancing turbidity removal at higher doses (Tarleton & Wakeman, 2007).

4.2.1.2.2 Hibiscus sabdarifa



For turbidity, the removal efficiency decreases with an increase in the dose. Excessive coagulant disrupts the delicate balance between coagulation and flocculation. This could be due to over-neutralization, too much coagulant can lead to over-neutralization. Instead of forming discrete flocs, particles may remain highly charged and repel each other. The other reason is excessive coagulant can create smaller flocs that are less efficient at settling. These tiny flocs may remain suspended in water, affecting water clarity. The removal efficiency of FC drastically increases with an increase in the dose. This indicates that the optimum hibiscus sabdariffa dose is 5mg/l for turbidity and 25mg/l for FC (Sibiya, 2023).

4.2.1.2.3 Aluminium sulphate



For turbidity, the removal efficiency of alum increases with an increase in the dose. Alum in water treatment dissociates into aluminum and sulfate ions, neutralizing negative charges on suspended particles. As alum dose increases, larger flocs form, settling more effectively during sedimentation. The removal efficiency of FC slightly decreases with an increase in the dose. At higher doses, alum can form excessively large flocs and these flocs may not settle effectively leading to re-suspension of particles. As a result, the fecal removal efficiency decreases. Therefore, the optimum hibiscus sabdariffa dose is 25mg/l for turbidity. (Hurst, Weber-Shirk, & Lion, 2017)

Correlations

		the dose of the coagulant (mg/l)	Turbidity (NTU)
the dose of the coagulant (mg/l)	Pearson Correlation	1	.334
	Sig. (2-tailed)		.380
	N	9	9
Turbidity (NTU)	Pearson Correlation	.334	1
	Sig. (2-tailed)	.380	
	N	9	9

Table 9 shows the correlation between coagulant dose and Turbidity

The Pearson correlation coefficient between the dose of the coagulant and turbidity is approximately 0.334. and the p-value associated with this correlation is 0.380. With a p-value greater than the common significance level of 0.05, we fail to reject the null

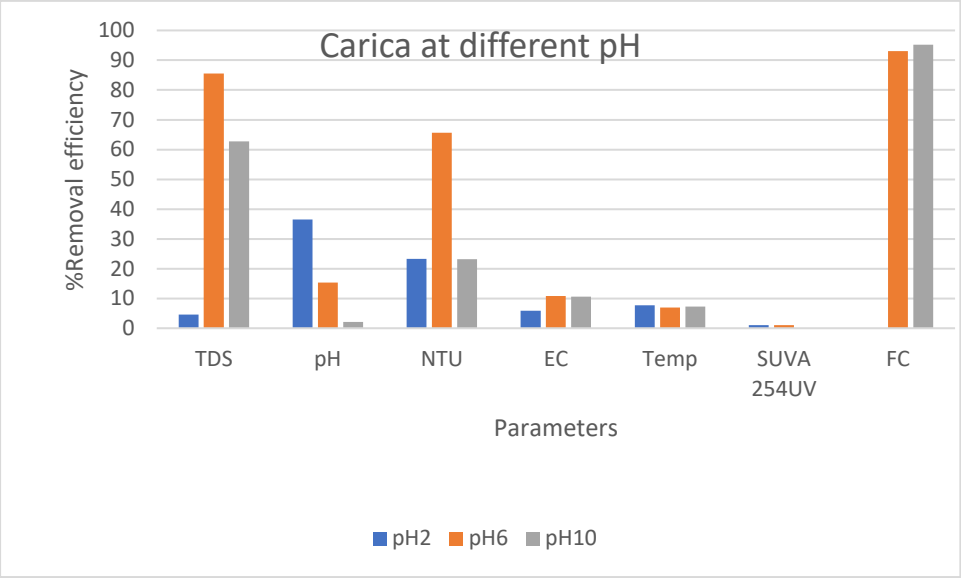
hypothesis but there is a positive but weak linear relationship between these two variables.

4.2.1.3 pH coagulation operating condition

PH		2			6			10		
Type of Coagulant	Parameter	initial	final	Treatment %	initial	final	Treatment %	initial	final	Treatment %
Papaya Carica	TDS	628	657	4.617834	1594	231	85.50816	1433	2332	62.73552
	pH	2	2.73	36.5	6	6.92	15.33333	10	10.21	2.1
	NTU	390	299	23.33333	102	35	65.68627	69	53	23.18841
	EC	1251	1325	5.915268	399	442	10.77694	2941	2630	10.57463
	Temp	24.6	26.5	7.723577	24.6	26.3	6.910569	24.6	26.4	7.317073
	SUVA 254UV	1.01	1	0.990099	1.01	1.02	0.990099	1.01	1.01	0
	FC	1000	1000	0	1000	69	93.1	1000	48	95.2
Hibiscus Sabdariffa	TDS	628	675	7.484076	1594	208	86.95107	1433	1341	6.420098
	pH	2	2.73	36.5	6	6.65	10.83333	10	10.19	1.9
	NTU	390	480	23.07692	102	66	35.29412	69	99	43.47826
	EC	1251	1347	7.673861	399	409	2.506266	2941	2705	8.024481
	Temp	24.6	26.6	8.130081	102	26.3	74.21569	24.6	26.6	8.130081
	SUVA 254UV	1.01	1	0.990099	1.01	1	0.990099	1.01	1.01	0
	FC	1000	1000	0	1000	1000	0	1000	56	94.4
Aluminum Sulphate	TDS	628	657	4.617834	1594	239	85.00627	1433	1219	14.93371
	pH	2	2.82	41	6	6.79	13.16667	10	10.19	1.9
	NTU	390	436	11.79487	102	33	67.64706	69	55	20.28986
	EC	1251	1308	4.556355	399	472	18.29574	2941	2655	9.724583
	Temp	24.6	26.7	8.536585	24.6	26.3	6.910569	24.6	26.6	8.130081
	SUVA 254UV	1.01	1	0.990099	1.01	0.99	1.980198	1.01	1.01	0
	FC	1000	1000	0	1000	1000	0	1000	1000	0

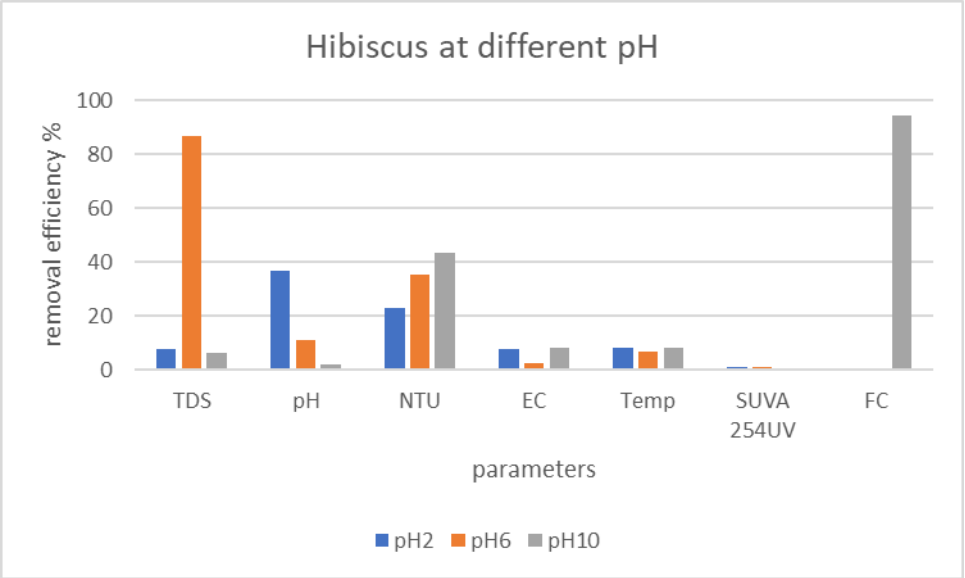
Table 10 Above Shows the pH operating condition

4.2.1.3.1 Carica Papaya



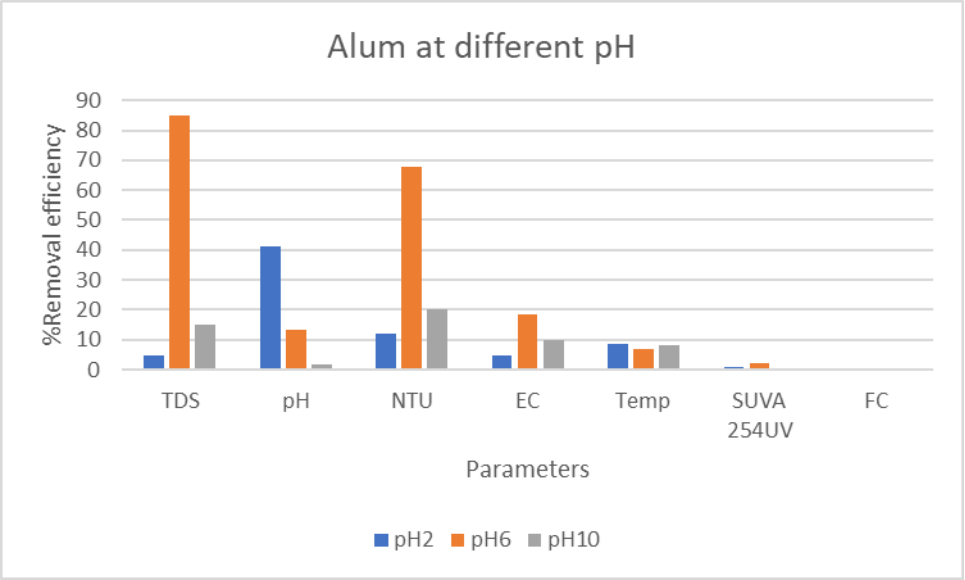
The pH plays a crucial role in Carica's performance for specific parameters. At pH 2, the removal efficiency for NTU is approximately 20%. Whereas at pH 6, NTU removal efficiency increases significantly to about 70% this is because it performs better in destabilizing suspended particles, allowing them to aggregate into larger flocs during flocculation, resulting in better sedimentation and improved turbidity removal. At pH 2, FC removal efficiency is close to zero as a pH that is too low may not allow the coagulation process to proceed. At pH 6 and pH 10, FC removal efficiency also approaches 100%. Alkaline conditions (pH 10) are most effective for reducing FC presence. Turbidity and TDS removal efficiency is higher at pH 6 and FC removal efficiency slightly increases from pH 6 to pH 10. pH 6 is the optimum condition for Carica papaya (Ernest, Onyeka, David, & Blessings, 2017).

4.2.1.3.2 Hibiscus sabdarifa



pH plays a role in Hibiscus's performance for specific parameters. Turbidity and FC removal efficiency is higher at pH 10. The removal efficiency increases as the pH increases as well as TDS removal efficiency is high at pH 6. At this pH, the surface charge of colloidal particles is close to neutral, and also hibiscus contains hydroxyl and carboxyl functional groups which are most active at this pH hence it helps in binding with coagulant particles. The pH range around 6 provides a good buffering capacity, this stability helps maintain the effectiveness of the hibiscus coagulant during the treatment process. This shows that pH10 is the optimum pH for Hibiscus in fecal removal (Okoro , Sharifi, Jesson, & Bridgeman, 2021).

4.2.1.3.3 Aluminium sulphate



Alum undergoes hydrolysis reaction with water to form aluminum hydroxide.

$Al_2(SO_4)_{3+}6H_2O \text{ ---}>2Al\ (OH)_3 + 3H_2SO_4$

Alum works by neutralizing the negative charge of suspended particles in water so at low pH (pH2) excessive aluminum hydroxide precipitation occurs, leading to poor settling and inefficient coagulation. pH plays a crucial role in Aluminum's performance for specific parameters. Turbidity and TDS removal efficiency are higher at pH 6. pH 6 is the optimum condition for Carica papaya. The results also show that there is no removal efficiency of fecal coliform at all the pH's (Harif, Khai, & Adin, 2012).

Correlations

		pH	Turbidity (NTU)
pH	Pearson Correlation	1	.206
	Sig. (2-tailed)		.595
	N	9	9
Turbidity (NTU)	Pearson Correlation	.206	1
	Sig. (2-tailed)	.595	
	N	9	9

Table 11 Above shows the correlation between pH and Turbidity

The Pearson correlation coefficient between pH and turbidity is 0.206 and the p-value associated with this correlation is 0.595. With a p-value greater than the common

significance level of 0.05, we fail to reject the null hypothesis that there is no significant linear relationship between pH and turbidity.

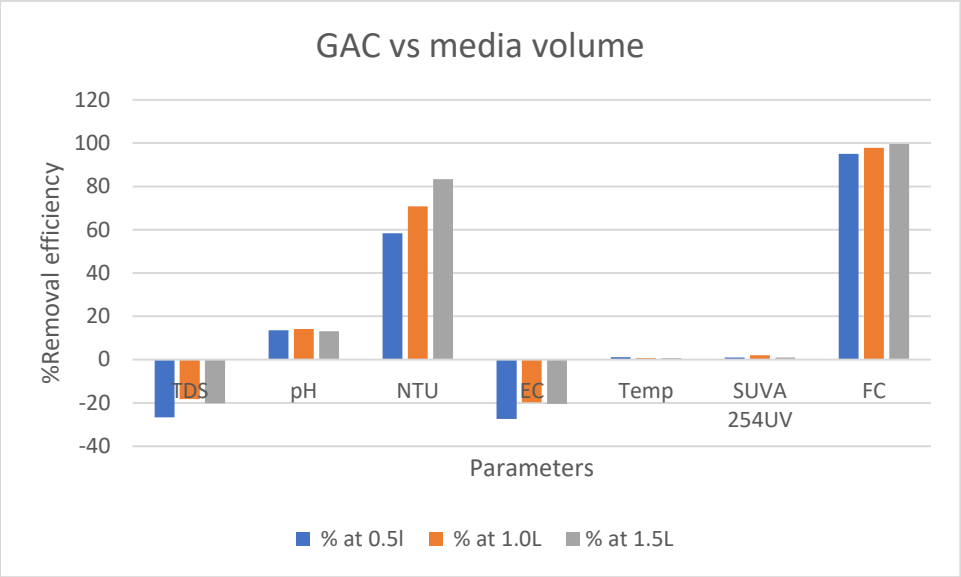
4.2.2. FILTRATION

4.2.2.1 volume of the adsorbent operating condition

Filter media Volume		0.5 L			1.0L			1.5L		
Type of filter media	Parameter	Initial	Final	Treatment%	Initial	Final	Treatment %	Initial	Final	Treatment%
Granular activated Charcoal	TDS	214	271	-26.6355	214	253	-18.2243	214	257	-20.0935
	pH	7	7.95	-13.5714	7	7.99	-14.1429	7	7.92	-13.1429
	NTU	24	10	58.33333	24	7	70.83333	24	4	83.33333
	EC	426	543	-27.4648	426	510	-19.7183	426	513	-20.4225
	Temp	27	26.7	1.111111	27	26.8	0.740741	27	26.8	0.740741
	SUVA 254UV	1.01	1	0.990099	1.01	0.99	1.980198	1.01	1	0.990099
	FC	1000	49	95.1	1000	21	97.9	1000	4	99.6
Corn cob Biochar	TDS	214	309	-44.3925	214	328	-53.271	214	322	-50.4673
	pH	7	8.18	-16.8571	7	8.29	-18.4286	7	8.1	-15.7143
	NTU	24	24	0	24	21	12.5	24	15	37.5
	EC	426	630	-47.8873	426	655	-53.7559	426	630	-47.8873
	Temp	27	26	3.703704	27	25.8	4.444444	27	26.1	3.333333
	SUVA 254UV	1.01	1	0.990099	1.01	0.96	4.950495	1.01	10.02	-892.079
	FC	1000	34	96.6	1000	29	97.1	1000	3	99.7
Bamboo Biochar	TDS	214	346	-61.6822	214	505	-135.981	214	547	-155.607
	pH	7	8.08	-15.4286	7	8.69	-24.1429	7	8.73	-24.7143
	NTU	24	15	37.5	24	9	62.5	24	8	66.66667
	EC	426	693	-62.6761	426	1052	-146.948	426	1080	-153.521
	Temp	27	26.6	1.481481	27	25.9	4.074074	27	26.1	3.333333
	SUVA 254UV	1.01	1	0.990099	1.01	1	0.990099	1.01	1	0.990099
	FC	1000	15	98.5	1000	9	99.1	1000	8	99.2

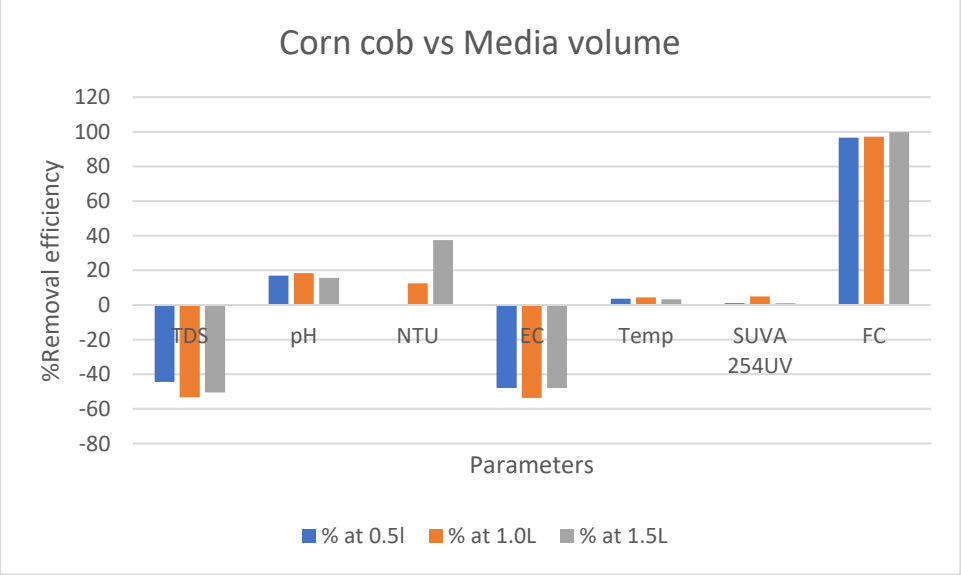
Table 12 The above shows different filter media

4.2.2.1.1 GAC



The removal efficiency of NTU and FC increases with the volume of media and is lowest at 0.5L and highest at 1.5L. Larger volumes can lead to higher efficiency because more adsorbent can be accommodated due to the large surface area. TDs removal efficiency increases as Gac media volume increases. Therefore 1.5L is indicated to be the optimum volume for GAC (Allendorf, , et al., 2018).

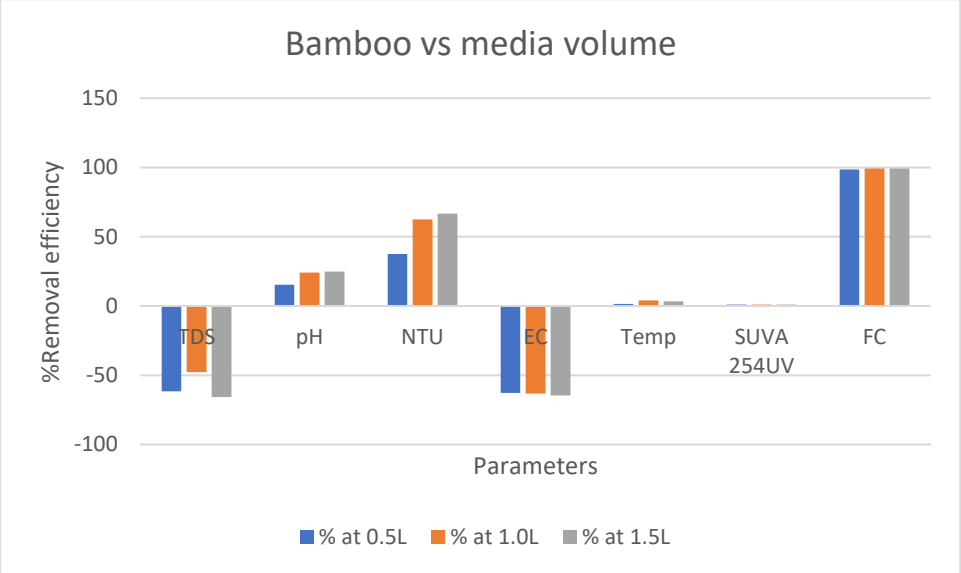
4.2.2.1.2 Corn Cob



The results indicate that NTU and FC removal efficiency increases with an increase in the volume of the filter media. This indicated that the optimal volume of the media is 1.5 for corncob biochar due to increased surface area. Larger volumes increase surface area, but

some ions may be released, causing an increase in TDS. Corn cob media adsorbs water, achieving equilibrium with the water's contaminant concentration. High TDS concentrations can cause the corn cob to become saturated, releasing adsorbent ions. Ion behavior and water chemistry also influence the adsorption process, with selective adsorption affecting overall TDS concentration. When an adsorbent (such as corn cobs) is added to water, it interacts with dissolved ions and impurities. Initially, as the adsorbent volume increases, more ions are adsorbed onto its surface, leading to an increase in TDS and EC (Mohan, Sarswat, Ok, & Pittman, 2014)

4.2.2.1.3. Bamboo

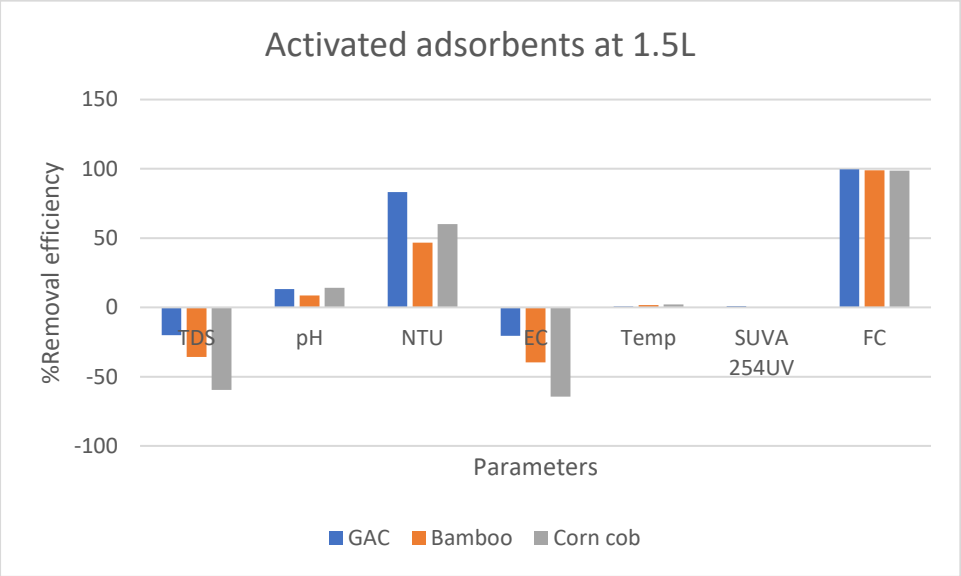


Bamboo appears to be an effective filter medium for various water quality parameters, as it shows an increase in removal efficiency of turbidity with consistent performance across different volumes on efficient removal of FC. Bamboo's natural antibacterial properties inhibit bacteria growth and survival, ensuring consistent water removal (Babu & Chandrasekhara, 2023). Its porous structure traps particles, including bacteria, for effective filtration. Over time, a biofilm forms on bamboo media, competing with harmful bacteria and enhancing its removal efficiency. The removal efficiency of NTU at different media volumes increases as the volume increases

4.2.2.2 Activated adsorbents operating condition

Filter media Volume		1.5L		
Type of filter Media	Parameter	Initial	Final	Treatment %
Granular activated Charcoal	TDS	214	257	-20.0935
	pH	7	7.92	-13.1429
	NTU	24	4	83.33333
	EC	426	513	-20.4225
	Temp	27	26.8	0.740741
	SUVA 254UV	1.01	1	0.990099
	FC	1000	4	99.6
Activated corn cob	TDS	304	485	-59.5395
	pH	7.68	6.6	14.0625
	NTU	15	6	60
	EC	600	986	-64.3333
	Temp	23.3	23.8	-2.14592
	SUVA 254UV	1.01	1.01	0
	FC	1000	13	98.7
Activated Bamboo	TDS	304	413	-35.8553
	pH	7.68	7.02	8.59375
	NTU	15	8	46.66667
	EC	600	838	-39.6667
	Temp	23.3	23.7	-1.71674
	SUVA 254UV	1.01	1.01	0
	FC	1000	10	99

Table 13 Above shows activated Filter media



After activation, the results show that the removal efficiency of TDS and EC of bamboo biochar decreases. Excessive phosphoric treatment might lead to pore collapsing or blockage. Corn cob biochar removal efficiency of TDS, turbidity, and EC increases after activation (Tomczyk, Sokołowska, & Boguta, 2020). The larger volume of adsorbent leads to more surface area available for adsorption. As the adsorbent surface area increases it interacts with more ions or dissolved solids, leading to high EC and TDS (Mohan, Sarswat, Ok, & Pittman, 2014).

4. Adsorption Equilibrium (Isotherm)

qi = (Co - Ceq) * v/m

SUVA was the parameter to calculate the isotherm for all adsorbents.

4.1 Granular activated carbon

Table 14 Below shows GAC isotherm

GAC	Co	Ceq	300g	600g	900g
0.5l	1.01	1	3.33*10^-5	1.67*10^-5	1.11*10^-5
1l	1.01	0.99	6.67*10^-5	3.33*10^-5	2.22*10^-5
1.5l	1.01	1	3.33*10^-5	1.67*10^-5	1.11*10^-5

The results show that SUVA has reduced from 1.01mg/l to 1 mg/l at 0.5L, at 1L it has reduced more to 0.99, and at 1.5Lmg/l SUVA has been reduced to 1mg/l. This might be due to less surface area at 0.5, and increased surface area at 1L and 1.5L due to increased surface area more organic matter might be on the adsorbent and end up being desorbed back into the water.

4.2 Corn cob

Table 15 Below shows corn cob isotherm

CORN COB	Co(mg/l)	Ceq(mg/l)	200g	400g	600g
0.5l	1.01	1	0.0005	0.00005	1.67*10^-5
1l	1.01	0.96	0.00025	0.000125	8.33*10^-5
1.5l	1.01	1	0.0005	0.00005	1.67*10^-5

The results show that SUVA has reduced from 1.01mg/l to 1 mg/l at 0.5L, at 1L it has reduced more to 0.96, and at 1.5Lmg/l SUVA has been reduced to 1mg/l. This might be due to less surface area at 0.5, and increased surface area at 1L and at 1.5L due to increased surface area more organic matter might be on the adsorbent and end up being desorbed back into the water.

4.3 Bamboo

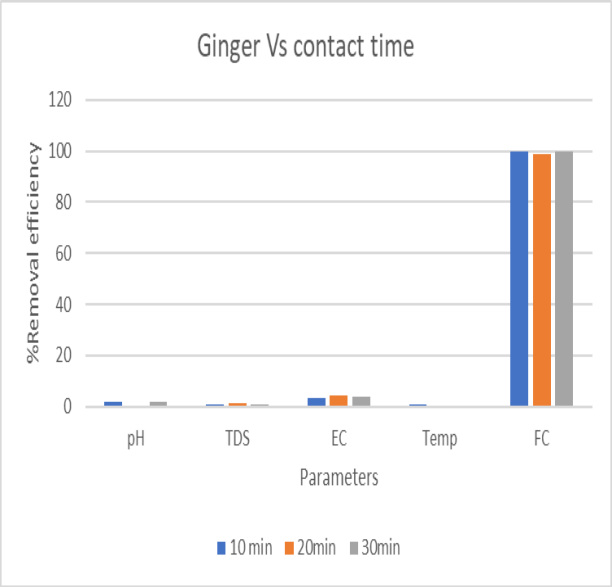
Table 16 Below shows Bamboo isotherm

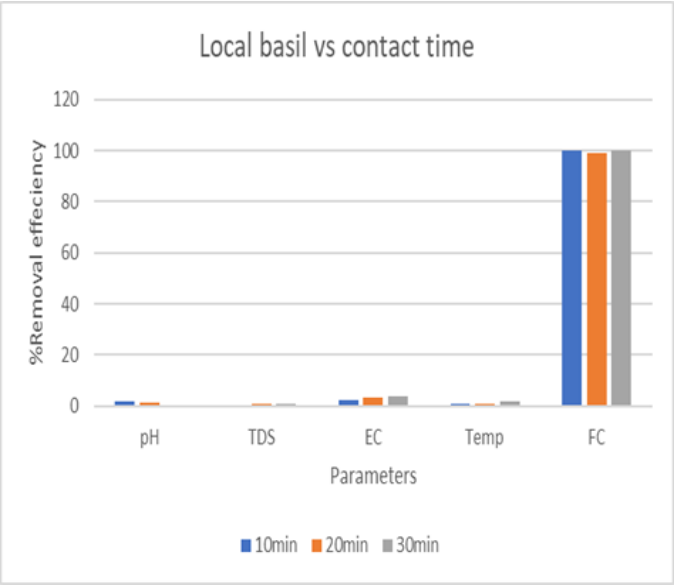
Bamboo	Co	Ceq	200g	400g	600g
0.5l	1.01	1	0.00005	0.000025	1.67*10^-5
1l	1.01	1	0.00005	0.000025	1.67*10^-5
1.5l	1.01	1	0.00005	0.000025	1.67*10^-5

For bamboo, the results show that the final organic matter for all volumes was the same for SUVA reduced from 1.01mg/L to 1mg/L. This indicates that the adsorption capacity is the same for all volumes to be used in bamboo.

4.2.3 DISINFECTION

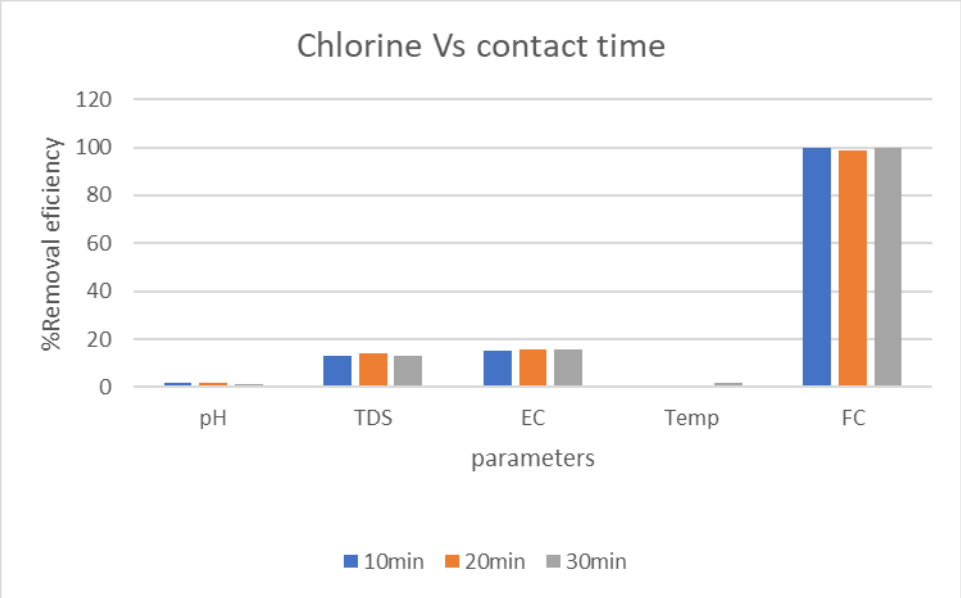
4.2.3.1 Contact time operating condition





The results show the disinfection kinetics and microbial behavior that explains why at 10min and 30min there is 100% removal efficiency of Fecal coliform. At 10 minutes of contact time, the disinfection process is rapid. Ginger and local basil effectively reduce microbial load (bacteria, viruses, etc.), and the high removal efficiency suggests efficient inactivation of pathogens. At 20min it shows recovery or regrowth of partially inactivated and it is observed by a decrease in removal efficiency. Some microorganisms that were partially inactivated by ginger may recover or regrow due to factors like resistance mechanisms or repair processes that contribute to this effect. At 30 min it indicated extended exposure which ensures thorough disinfection, by extending the contact time to 30 minutes, some recovery/regrowth can be overcome (LeChevallier & Augustine , 2004)

4.3 Chlorine contact time



At 10 minutes, it is said to be a short contact time, and the initial disinfection is rapid. Most of the fecal coliforms are inactivated, resulting in nearly 100% removal efficiency. At 20 minutes as the contact time increases, the disinfection process continues, but it reaches a point where the remaining fecal coliforms become more resistant. Some may survive or exhibit partial inactivation thus leading to the removal efficiency dropping to 90%. Extended contact time at 30 minutes further affects any remaining resistant fecal coliforms. The additional exposure ensures that nearly all of them are inactivated, leading to another spike in removal efficiency to 100%. The removal efficiency of TDS and EC increases to 15% (Sharma & Bhattacharya, 2016).

Correlations

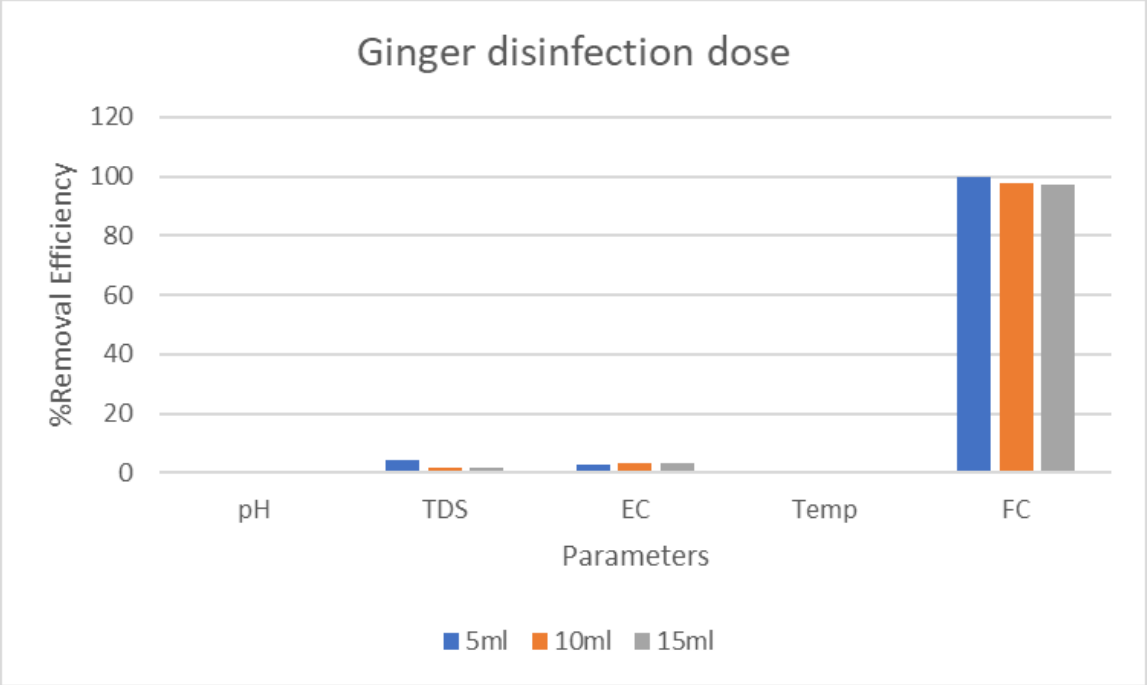
		contactime	FC
Contactime	Pearson Correlation	1	.000
	Sig. (2-tailed)		1.000
	N	9	9
FC	Pearson Correlation	.000	1
	Sig. (2-tailed)	1.000	
	N	9	9

Table 17 above shows the correlation between contact time and FC

The Correlation between contact time and removal efficiency of Fecal coliform shows that the removal of fecal coliform in the water is dependent on the amount of time the disinfectant is in contact with the water being treated.

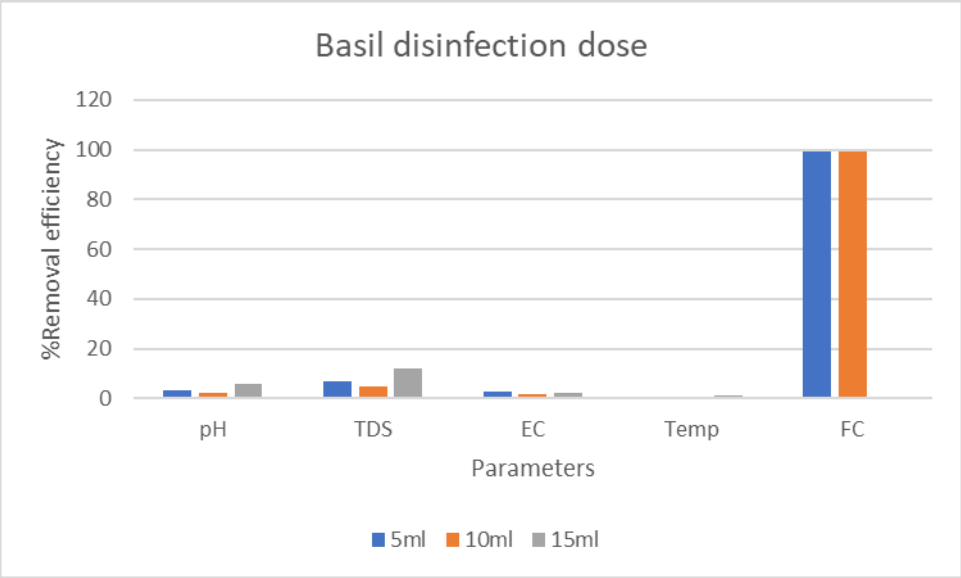
4.2.3.2 Disinfectant Dose Operating Condition

4.2.3.2.1 zingiber officinale Roscoe



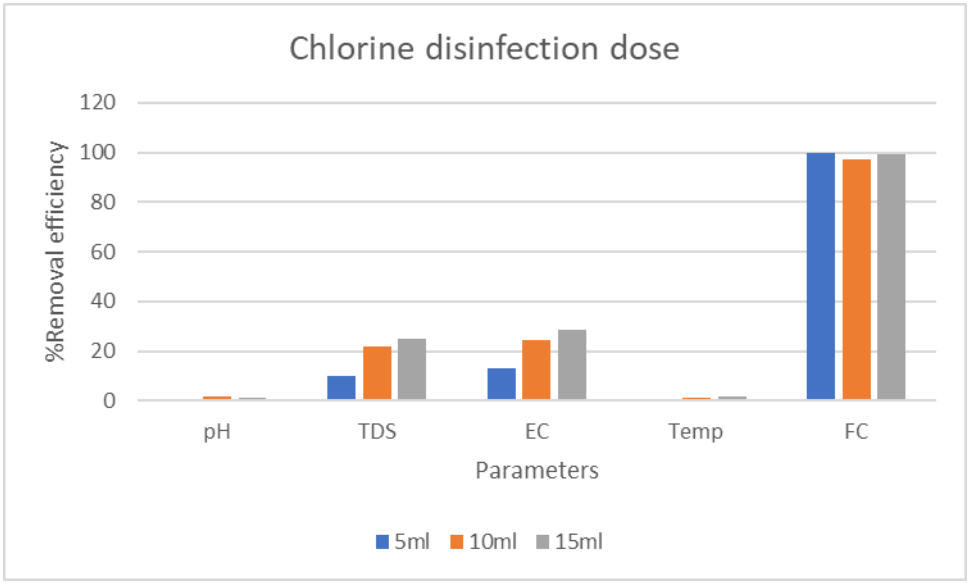
A slight decrease in the removal efficiency of fecal coliform with an increase in disinfectant dose. Ginger contains various bioactive compounds, including phenolic compounds, flavonoids, and terpenoids, and at low doses, these compounds may exhibit antimicrobial properties and enhance disinfection (Watson, Farré, & Knight, 2012). However, they can interact with chlorine or other disinfectants at higher doses, leading to reduced effectiveness. Some compounds in ginger may form complexes with chlorine, reducing its availability for disinfection. It follows a dose-response curve like any disinfectant thus means beyond the optimal dose antimicrobial activities may decline. The optimum dose for Ginger is 5ml with 100% efficiency (Peleg, 2020)

4.2.3.2.2 local basil Dose



The results show that with a 15ml dose, there is no treatment for fecal coliform and this indicates that Basil follows a dose-response curve like any disinfectant thus means beyond the optimal dose antimicrobial activities may decline. The optimum dose falls between the range of 5 ml to 10 ml with 100% efficiency (Peleg, 2020) . For TDS the maximum removal efficiency is observed at the dose of 15ml with 12%.

4.2.3.2.3 chlorine Dose



The removal efficiency of FC significantly increases with lower chlorine doses, therefore at a 5ml chlorine dose, the removal efficiency is 100%. At a 10ml dose, it reaches around 97%. Disinfection processes often exhibit diminishing returns. At lower doses (5ml), the

active chlorine effectively interacts with contaminants, leading to higher removal efficiency (Peleg, 2020). As the dose increases, the impact plateaus or even declines due to saturation. At higher doses(15ml), chlorine may react with other water constituents (e.g., organic matter) and these interactions can reduce its availability for disinfection. TDS removal efficiency remains relatively low across all chlorine doses but it increases as the dose increase. Unlike FC, TDS removal is not significantly impacted by chlorine dose (Watson, Farré, & Knight, 2012).

Correlations

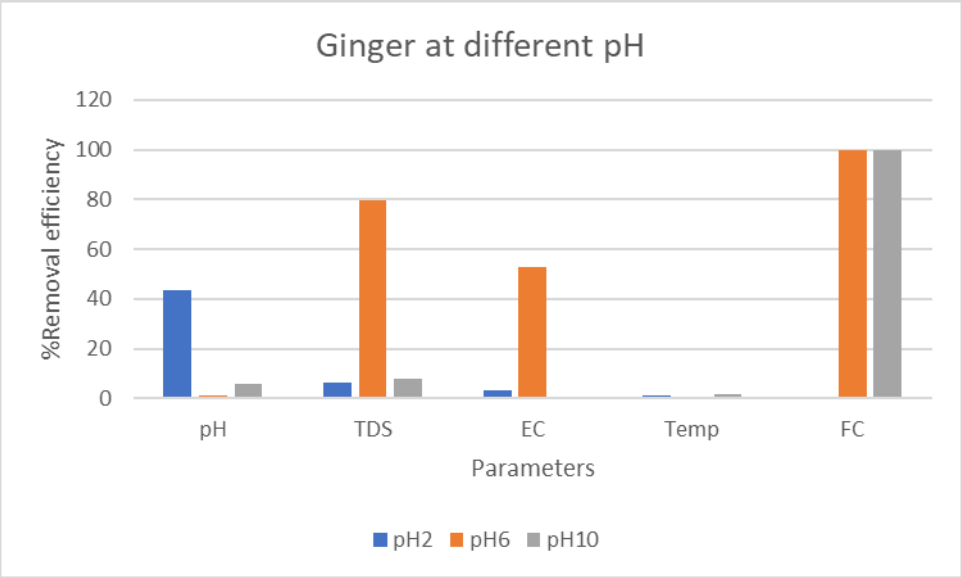
		DisDose	FC
DisDose	Pearson Correlation	1	-.451
	Sig. (2-tailed)		.223
	N	9	9
FC	Pearson Correlation	-.451	1
	Sig. (2-tailed)	.223	
	N	9	9

Table 18 Above shows the correlation between disinfection dose and Fc

The above correlation shows that with a p-value greater than 0.05, we fail to reject the null hypothesis that there is no significant correlation. Therefore, there is no strong evidence to suggest a significant linear relationship between the dose of the disinfectant and FC.

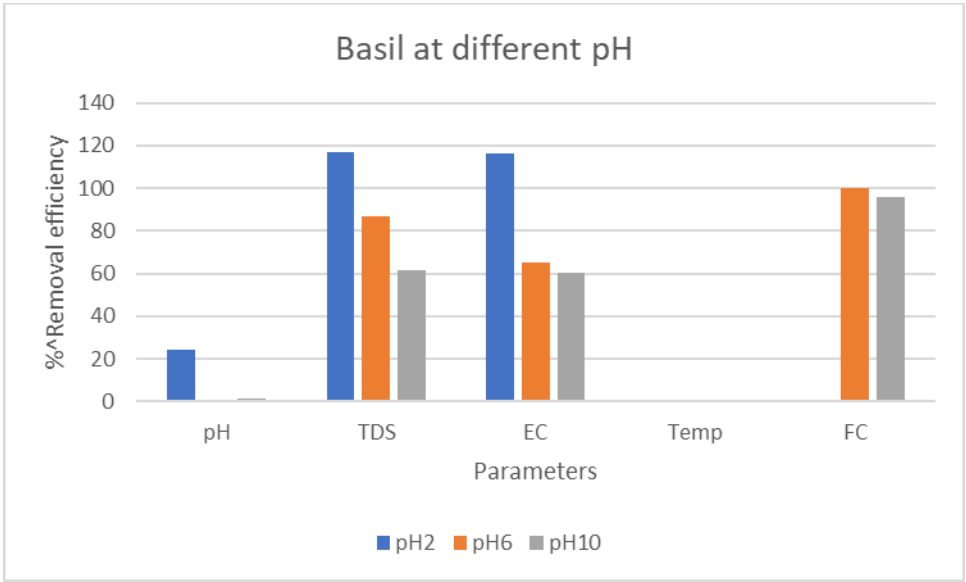
4.3.2.3 pH operating condition

4.3.2.3.1 zingiber officinale roscoe



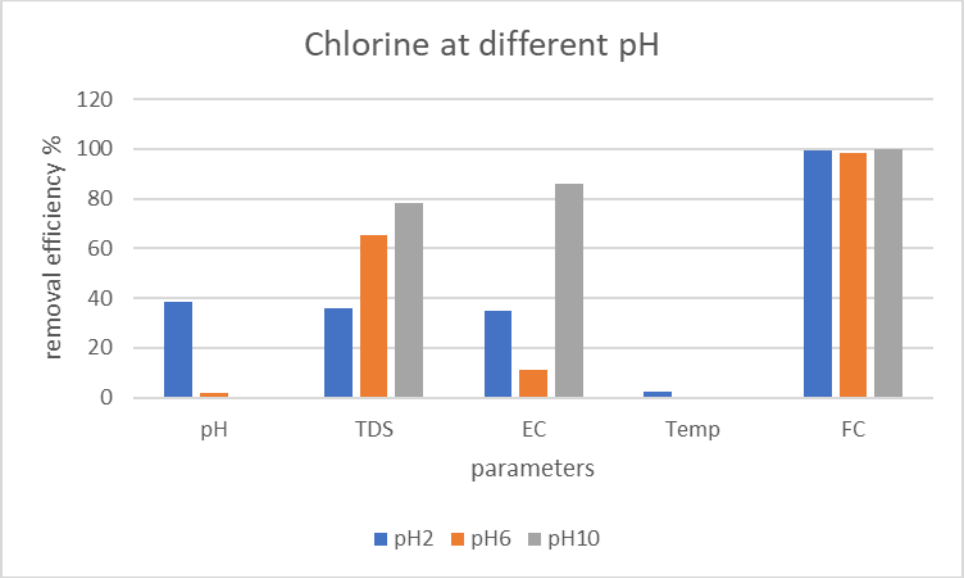
The results show that the removal efficiency of fecal coliform is higher at pH 10 and pH 6. The acidic environment at pH 2 affects antimicrobial properties and the optimum pH operating condition ranges from 6-10 which indicates that the performance of ginger favours alkaline conditions. Ginger contains natural compounds like gingerol and shogaol, these compounds have functional groups such as phenolic hydroxyl groups that can ionize (Mao, et al., 2019). These functional groups are more reactive at higher pH. The removal efficiency of TDS and EC increases at pH 6, ionized ginger compounds can better interact with TDS and EC ions, leading to improved removal.

4.3.2.3.2 Local Basil at Different pH



At pH 6 the results show a higher efficiency of 100% removal of fecal coliform. Basil's antimicrobial compounds such as eugenol and linalool exhibit varying effectiveness at different pH levels. At a higher pH more alkaline conditions these compounds may become less active against fecal coliform. As the pH increases, the ionization of basil compounds changes, and some antimicrobial functional groups lose their reactivity thus affecting disinfection efficacy (Valsan, et al., 2022). Thus, why at pH 10 the efficiency has decreased. The removal efficiency of TDS and EC decreases as the pH increases this so because at higher pH the essential compounds become less soluble hence reducing the effectiveness of removing TDS (Sylvia , Michael , Bruce, & Weiss, 2005).

1.1 Chlorine at pH



At pH 10 the results show a higher removal efficiency of 100% of Fecal coliform. At pH 2 and 6 the efficiency has slightly decreased, at pH2 disinfection efficiency is close to 100% because most of the chlorine is in its active form. At pH 6, water is closer to neutral. The balance between HOCl and hypochlorite ion (OCl^-)shifts. OCl^- is less effective as a disinfectant. Hence, the efficiency decreases to around 98%. Surprisingly at pH 10, it remains 100% efficient this is so possibly due to specific water characteristics that we used in the experiment. As pH rises, the efficiency of coagulation and flocculation processes improves, aiding in the removal of suspended particles, organic

matter, and dissolved solids thus increasing the removal efficiency of TDS and EC although chlorine is used as a disinfectant, not a coagulant (Kekes, Tzia , & Kolliopoulos, 2023).

Correlations

		pHop	FC
pHop	Pearson Correlation	1	.671*
	Sig. (2-tailed)		.048
	N	9	9
FC	Pearson Correlation	.671*	1
	Sig. (2-tailed)	.048	
	N	9	9

*. Correlation is significant at the 0.05 level (2-tailed).

Table 19 Above shows the correlation between pH and FC

The significance level associated with this correlation is 048. In this case, the value is less than .05, which suggests statistical significance at the 0.05 level (2-tailed). The positive correlation between pHop and FC implies that changes in pHop may be related to changes in FC.

4.2.4 COMPARING RESULTS WITH THE MBS DRINKING WATER STANDARDS

Recommended limits of the parameters by MBS 214: 2013

Table 20 shows the MBS recommended parameters limits

Parameter	Recommended upper limit (ranges)
TDS	500
pH	6.5-8.5
NTU	0.1-1
EC	70-150
Temp	
SUVA 254UV	
FC	1-10

Coagulant experiment: Dose of the coagulant

Table 21 Shows dose of the coagulants based on MBS

Dose	Parameter	5mg/L	15mg/L	25mg/L
Type of coagulant	TDS	Below	Below	Below
Papaya Carica	pH	Within	Within	Within
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA 254UV			
	FC	Above	Above	Within
Hibiscus Sabdariffa	TDS	Below	Below	Below
	pH	Within	Within	Within
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA 254UV			
	FC	Above	Within	Above
Aluminium Sulphate	TDS	Below	Below	Below
	pH	Within	Within	Within

NTU	Above	Above	Above
EC	Above	Above	Above
Temp			
SUVA 254UV			
FC	Above	Above	Above

From the table above, all the three types of coagulants have TDS and pH values below the recommended 500 mg/L and between 6.5-8.5 of the MBS drinking water quality standards respectively. However, all the EC, turbidity and fecal coliform values are above the accepted limits as shown in the first table above. Therefore, these three are not reliable in coagulating water.

Coagulation Experiment: Mixing speed

Table 22 Shows MBs standards to that of local materials

Mixing speed		120 RPM	160 RPM	200 RPM
Type of coagulant	Parameter			
Papaya Carica	TDS	Below	Below	Below
	pH	Within	Within	Within
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA 254UV			
	FC	Above	Above	Above
Hibiscus Sabdariffa	TDS	Below	Below	Below
	pH	Within	Within	Within
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA			

	254UV			
	FC	Above	Above	Above
Aluminium Sulphate	TDS	Below	Below	Below
	pH	Within	Within	Within
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA 254UV			
	FC	Above	Above	Above

Under the mixed speed conditions, the TDS and pH have values below the recommended 500 mg/L and between 6.5-8.5 of the MBS drinking water quality standards respectively. The faecal coliform, electrical conductivity and turbidity have values above the maximum acceptable concentrations.

Coagulation Experiment: PH operating condition

Table 23 Coagulation MBs standards

pH		2	6	10
Type of coagulant	Parameter			
Papaya Carica	TDS	Above	Below	Above
	pH	Below	Within	Above
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA 254UV			
	FC	Above	Above	Above
Hibiscus Sabdariffa	TDS	Above	Below	Above
	pH	Below	Within	Above
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA 254UV			

	FC	Above	Above	Above
Aluminium Sulphate	TDS	Above	Below	Above
	pH	Below	Within	Above
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA 254UV			
	FC	Above	Above	Above

Having water with a lower pH (2), the resultant pH of the water when coagulated is below the acceptable MBS water quality standards in all three types of coagulants. When the pH of the water is 6, the resultant quality of the water about the respective coagulants is within the acceptable pH ranges and for pH (10), it is above the recommended maximum pH value. For TDS, EC, turbidity and faecal coliform, the resultant water quality for all three types of coagulants is not acceptable except for TDS at the pH of 6. Therefore, all three coagulants show better performance when the pH is set at 6.

FILTRATION

Table 24 Filtration MBS standards

Filter Media Volume		0.5 L	1 L	1.5L
Type of filter media	Parameter			
Granular Activated Charcoal	TDS	Below	Below	Below
	pH	Within	Within	Within
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA 254UV			
	FC	Above	Above	Above

Corn cob Biochar	TDS	Below	Below	Below
	pH	Within	Within	Within
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA 254UV			
	FC	Above	Above	Above
Bamboo Biochar	TDS	Below	Above	Above
	pH	Within	Above	Above
	NTU	Above	Above	Above
	EC	Above	Above	Above
	Temp			
	SUVA 254UV			
	FC	Above	Above	Above

For the three types of filter media, the pH values are within the acceptable ranges of 6.5-8.5 for 0.5L media volume. The pH is falling above the maximum acceptable range for the granular activated charcoal and corn cob char so is TDS. For bamboo biochar, the TDS is above the acceptable value of 500 mg/L. All the values of turbidity, EC and faecal coliform are above the MBS standards. Hence, granular activated charcoal and corn cob biochar is better than bamboo biochar under all three media volumes.

Activated Filter Media

Table 25 MBS standards on Activated media

Filter Media Volume		1.5L
Type of filter media	Parameter	
Granular Activated Charcoal	TDS	Below
	pH	Within
	NTU	Above
	EC	Above
	Temp	
	SUVA 254UV	
	FC	Above

Corn cob Biochar	TDS	Above
	pH	Within
	NTU	Above
	EC	Above
	Temp	
	SUVA 254UV	
	FC	Above
Bamboo Biochar	TDS	Above
	pH	Within
	NTU	Above
	EC	Above
	Temp	
	SUVA 254UV	
	FC	Above

Under activated filter media, all three types of filter media have pH values within the acceptable MBS standards. The rest of the parameters are above the acceptable ranges for all the types of filter media except for TDS under the granular activated charcoal which is below the acceptable range of 500. Therefore, activating these filter media does not improve the overall water quality.

DISINFECTION

Contact time

Table 26 MBS on disinfection

Contact time		10 Min	20 Min	30 Min
	Parameter			
Ginger	TDS	Below	Below	Below
	pH	Within	Within	Within
	EC	Above	Above	Above
	Temp			
	FC	Within	Above	Within
Basil	TDS	Below	Below	Below
	pH	Within	Within	Within

	EC	Above	Above	Above
	Temp			
	FC	Within	Above	Within
Chlorine	TDS	Below	Below	Below
	pH	Within	Within	Within
	EC	Above	Above	Above
	Temp			
	FC	Within	Above	Within

For all three types of disinfectants, the changes in the contact time do not vary their water treatment capabilities as seen from the table above. This means that their differences in water treatment efficiency can be significantly observed over longer periods.

Dose of the disinfectant

Table 27 dose of disinfectants(MBS)

Disinfection dose		5ml	10ml	15ml
	Parameter			
Ginger	TDS	Below	Below	Below
	pH	Within	Within	Within
	EC	Above	Above	Above
	Temp			
	FC	Within	Above	Above
Basil	TDS	Below	Below	Below
	pH	Within	Within	Within
	EC	Above	Above	Above
	Temp			
	FC	Above	Above	Above
Chlorine	TDS	Below	Below	Below
	pH	Within	Within	Within
	EC	Above	Above	Above
	Temp			
	FC	Within	Above	Above

For all the three doses of disinfection, there are no unique variations in terms of water quality because all these water treatment materials have shown similar water quality values according to the MBS standards.

pH

Table 28 MBS pH standards

pH		pH 2	Ph 6	Ph 10
	Parameter			
Ginger	TDS	Below	Below	Below
	pH	Below	Below	Above
	EC	Above	Above	Above
	Temp			
	FC	Above	Within	Within
Basil	TDS	Above	Below	Above
	pH	Below	Below	Above
	EC	Above	Above	Above
	Temp			
	FC	Above	Within	Above
Chlorine	TDS	Above	Above	Above
	pH	Below	Below	Above
	EC	Above	Above	Above
	Temp			
	FC	Above	Above	Within

From the table above, pH of 6 provides water quality with nearly acceptable characteristics as compared to the pH of 2 and 10. Hence, all these three treatment chemicals / materials can work better when the pH of the water is around 6. For the other parameters such as TDS, FC and EC, all the treatment materials have shown similar water quality values for all the three pH. Hence, the pH of around 6 can help better to meet the MBS water quality standards.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

Locally available materials have the potential to treat drinking water as some of the parameters after treatment were falling within the acceptable limits by the MBS, and the locally available materials that were used were identified to work differently under different operating conditions. These materials were also proven to be cost-effective Some of these materials were identified to have multiple uses in water treatment processes for example Carica papaya which was used as a coagulant but portrayed traits of being a good disinfectant.

5.2 RECOMMENDATION

The investigation of the long-term performance and scalability of locally sourced materials needs to be conducted, to ensure that locally sourced materials do not introduce health risks like contaminants by assessing their potential hazards during material handling and treatment.

Multiple local materials to be identified to reduce dependence on the few available materials which can help in having more alternative materials in cases of shortages and quality issues. This can help in the Implementation of the findings with the local communities in water treatment using locally sourced materials to encourage the adoption of these materials.

More research needs to be done to Evaluate the properties of local materials for example porosity and adsorption capacity of the local materials under different conditions to understand their behavior. And how the materials can be preserved to make sure that they maintain their treatment capacity.

Utilizing local resources can encourage entrepreneurship and small-scale businesses because Communities can engage themselves in material collection, processing, and distribution, therefore, creating more economic opportunities for all.

Locally available materials are often more affordable than imported or specialized materials. Therefore, Reduced costs in material procurement can contribute to overall cost savings in water treatment projects.

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APPENDICES

Appendix 1: MUST DAM



Appendix 2: Design setup(filtration)

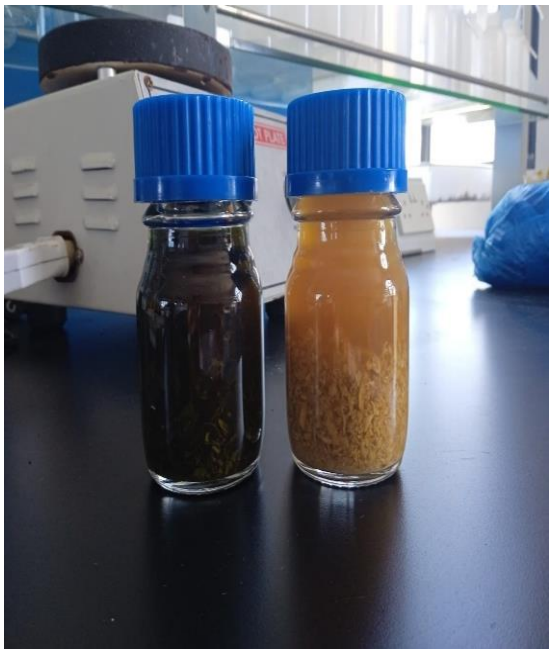


Appendix 3.

Local basil leaves



Local basil and ginger stock solution



Dried Carica seeds



Alum, Hibiscus, and Carica stock solution



Appendix 4.

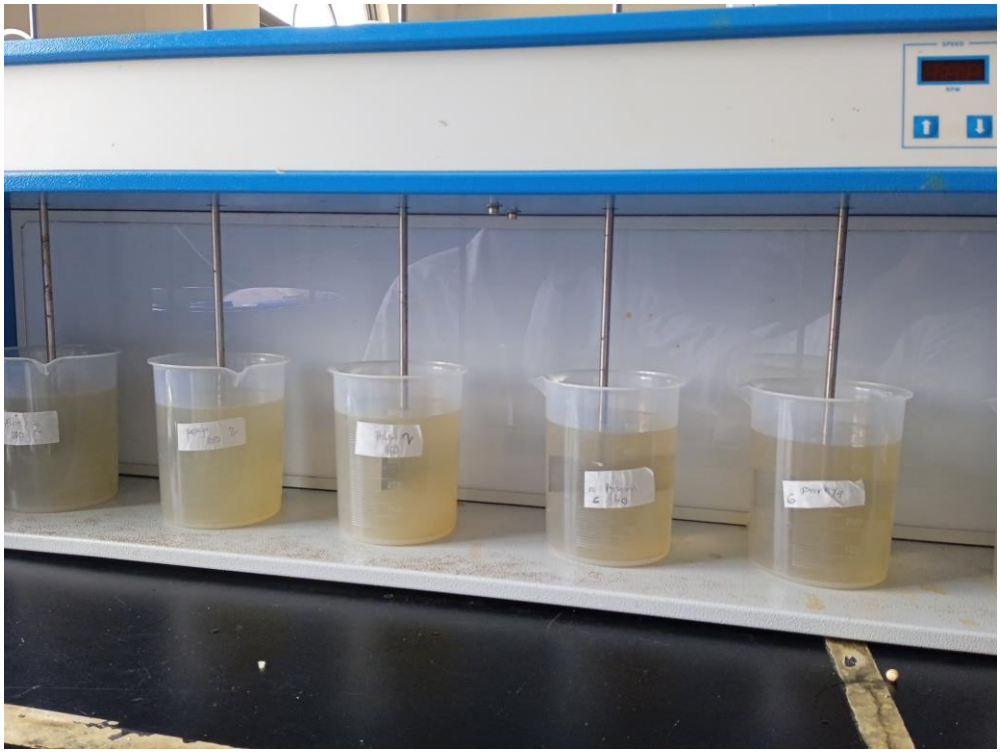
Preparation of bamboo and corn cob biochar




Appendix 5. Laboratory experiments



Coagulation process using Jar test



Settling of flocs



Relationship on the operating condition and the targeted paramete

Filtration

Correlations

		Adsorbenttype	Adsorbentvolu	TDS	pH	NTU	EC	SUVA	FC	TEMP
Adsorbenttype	Pearson Correlation	1	-.025	.907**	.962**	-.237	.970**	-.108	.389	.602
	Sig. (2-tailed)		.950	<.001	<.001	.539	<.001	.782	.301	.086
	N	9	9	9	9	9	9	9	9	9
Adsorbentvolu	Pearson Correlation	-.025	1	-.010	-.075	.359	-.049	.080	.706*	.237
	Sig. (2-tailed)	.950		.980	.848	.343	.901	.837	.033	.540
	N	9	9	9	9	9	9	9	9	9
TDS	Pearson Correlation	.907**	-.010	1	.827**	-.448	.957**	.082	.259	.669*
	Sig. (2-tailed)	<.001	.980		.006	.227	<.001	.833	.502	.049
	N	9	9	9	9	9	9	9	9	9
pH	Pearson Correlation	.962**	-.075	.827**	1	-.082	.906**	-.069	.332	.476
	Sig. (2-tailed)	<.001	.848	.006		.834	<.001	.859	.383	.196
	N	9	9	9	9	9	9	9	9	9
NTU	Pearson Correlation	-.237	.359	-.448	-.082	1	-.408	-.395	.399	-.603
	Sig. (2-tailed)	.539	.343	.227	.834		.275	.292	.287	.086
	N	9	9	9	9	9	9	9	9	9
EC	Pearson Correlation	.970**	-.049	.957**	.906**	-.408	1	.043	.259	.733*
	Sig. (2-tailed)	<.001	.901	<.001	<.001	.275		.913	.500	.025
	N	9	9	9	9	9	9	9	9	9
SUVA	Pearson Correlation	-.108	.080	.082	-.069	-.395	.043	1	-.249	.358
	Sig. (2-tailed)	.782	.837	.833	.859	.292	.913		.518	.344
	N	9	9	9	9	9	9	9	9	9
FC	Pearson Correlation	.389	.706*	.259	.332	.399	.259	-.249	1	.082
	Sig. (2-tailed)	.301	.033	.502	.383	.287	.500	.518		.833
	N	9	9	9	9	9	9	9	9	9
TEMP	Pearson Correlation	.602	.237	.669*	.476	-.603	.733*	.358	.082	1
	Sig. (2-tailed)	.086	.540	.049	.196	.086	.025	.344	.833	
	N	9	9	9	9	9	9	9	9	9

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).