JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENVIRONMENTAL ENGINEERING CHAIR

ASSESSMENTS ON THE EFFICIENCY OF ALUMINUM SULFATE AND OKRA SEED COAGULANTS FOR DRINKING WATER TREATMENT:

IN THE CASE OF GAMBELLA TOWN.

A Thesis submitted to School of Graduate Studies, Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree Master of Science in Environmental Engineering

By

Hagos Gebru Kahsay

October, 2021
Jimma, Ethiopia

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Advisor: Zerihun Asmelash (PhD Ass, Prof.)

Co-Advisor: Miss Kidist Jemal (MSc)

October, 2021
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DECLARATION

All the contents of this research were conducted by the author, Hagos Gebru Kahsay, with the supervision of Zerihun Asmelash **(**PhD Ass**,** Prof**.)**. I had performed the practical experiments mentioned in this research under the supervision of Miss Kidist Jemal (Msc) & Firomsa Bidira (MSc) staff of JIT (lab technician). The experimental part of this research had been conducted in the Department of Civil & Environmental Engineering, Jimma Institute of Technology. This thesis is expected to satisfy the partial fulfillment for M.Sc. degree in Environmental Engineering. To the best of the author, this work has not been used for the award of any degree or diploma, but I would like to extend my heartfelt gratitude for the researchers whose work that has been referred in my thesis.

Hagos Gebru ____________________ ____________________

Name (Student) Signature Date

Zerihun Asmelash (PhD Ass, Prof.) ____________________ ____________________

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Miss Kidist Jemal (MSc) ____________________ ____________________

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Mr. Seifu Kebed (MSc) ____________________ ____________________

Chair holder Signature Date

ACKNOWLEDGEMENTS

First, I would like to thank The Almighty God for being there for all my needs. In addition, I would like to thank Zerihun Asmelash **(**PhD Ass**,** Prof**.)** my advisor and Miss Kidist Jemal **(**MSc**)** the Co-Advisor for their guidance and support during the preparation of this research. Finally, to the successful completion of this Research work, for all those who have lent a helping hand in any way and shared ideas large or small.

My special and great thanks goes to my beloved Wife Zemedamariam Birhan who has been providing me with her love, support and encouragement, the Necessary help during my academic careers. Without her consistent help and advice this wouldn't be real I am very proud to be part of such beautiful family.

ABSTRACT

The treatment of drinking water by established treatment methods in developing and underdeveloped countries is also very costly and unacceptable, due to the lack of adequate infrastructure and accessories needed and also due to the hazards caused by the chemicals used in the treatment process. The efficiency assessment of aluminum sulfate and okra seed coagulants has been tested in the following study. Using the water sample collected from the Baro River, this efficiency was checked by standard Jar Tests performed at Jimma University, Jimma Institute of Technology (JIT). The efficiency was specified by the quantity of turbidity removal, confirming the efficient turbidity removal of Okra was 98.113% at pH3 and dosage of 0.5g & Alum was 99.8% at pH3 and dosage of 1.5g ranges at a volume of 500 ml.

In terms of the assessment of its operation and performance, conventional water treatment plants, particularly in developing countries, face major challenges due to inappropriate technologies, insufficient equipment and a lack of qualified expertise. Therefore, simple but efficient technologies are necessary for a reasonable evaluation of the plant's daily performance. Turbidity is considered to be a suitable replacement to provide a favorable indication of the biological and physical content of the treated water, thereby providing a fair gauge of the treatment plant's efficiency with regard to water purification by extension. In addition, it is reasonably easy to calculate, cheap and the operators can easily understand it. In this report, the efficiency of the water treatment plant in Gambella town was assessed.

The research was performing by evaluating the efficiency of Aluminum sulfate & Okra seed coagulants in Gambella town. Aluminum sulfate is very expensive, and people's ability to pay for services is limited. Skills and technology are also scarce. As a result, locally available materials can be used to achieve a long-term safe water supply and suggesting effective and relevant solutions to investigate.

Keywords: *Okra Seeds, Aluminum sulfate, Coagulant, Turbidity*

DEDICATION

I dedicate this thesis to my Wife Zemedamariam Birhan, and to my Daughter Ziema Hagos, for helping me with affection, love and for their dedicated partnership in the success of my life.

TABLE OF CONTENTS

List of Tables

List of Figures

Acronyms

AWWA	American Water Works Association
CCP	Composite Correction Program
CPE	Comprehensive Performance Evaluation
CT	Times contact
ESWTR	Enhanced Surface Water Treatment Rule
GWTP	Gambella Water Treatment Plant
NTU	Nephelometric Turbidity Unit
RPM	Rotation Per Minute
RSF	Rapid Sand Filter
SWTR	Surface Water Treatment Rule
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
MO	Moringa Oleifera
CP	Coagulant Protein
NRW	non-revenue water
UFW	unaccounted-for water

CHAPTER ONE

INTRODUCTION

1.1 Background

Water is one of the most important resources for the growth of economic and non-economic activities of all kinds. Of all public services, sustainable arrangements for sufficient and healthy drinking water are the most relevant. Water needed for drinking purposes is further stressed by the continuously increasing population and there is a need to replace the traditional and obsolete methods of designing water distribution networks with accurate, speedy and computer-based software and methods to meet this ever-increasing demand at urban as well as rural level. The use of chemical coagulants for wastewater coagulation has various consequences, such as their ability to cause diseases. (Access, 2020), the possibility of water pollution or surface runoff of treated water containing high residual aluminum concentration and therefore their use for the wastewater treatment is not an eco-friendly option. On the other hand, the use of natural substances for coagulation in place of chemicals is a promising alternative for the treatment of wastewater. Natural coagulants are safe for consumption (owing to their plant-origins) and are biodegradable in the environment (Nath et al., 2020).

Although safe drinking water is one of the necessities for humans, there is no access to safe drinking water for billions of people around the world. A substantial number of people are from developing countries. The most vulnerable parts of society are women and children in particular. Each day in the World and in Ethiopia significant number of children are dying due to lack of safe drinking water, for appropriate sanitation and hygiene(Mwakabona et al., 2017).

Both dissolved and suspended particles comprise groundwater and surface water. To separate the suspended solids segment from the water, coagulation and flocculation are used. Suspended particles vary in source, charge, particle size, shape, and density. These factors depend on the proper application of coagulation and flocculation. Suspended solids have a negative charge in water and, since they have the same form of surface charge, as they come close together, they repel each other. Suspended solids will also remain suspended and will not clump together and settle out of the water unless sufficient coagulation and flocculation are used. (Prakash et al., 2014).

To neutralize the negative charges on non-settleable solids, coagulant chemicals with charges opposite those of the suspended solids are applied to the water (such as clay and color-producing organic substances). The tiny suspended particles are capable of holding together until the charge is neutralized. These slightly larger particles, which are not apparent to the naked eye, are called micro flocs. It should be obvious that water surrounds the newly developed micro flocs. If not, there was no neutralization of coagulation and some of the particle charges. It may be appropriate to add more coagulant chemicals to (Prakash et al., 2014).

Small institutional capacity is also one of the obstacles hindering cities in developing countries from handling their infrastructure assets in general and their supply of water in particular. In addition to, too little coverage, water losses (physical loss) in urban water supply account for more than 50 percent of the supplies that mainly result from leakage of pipes, joints and valves, flowing service reservoirs and waste of water through illegal connections and non-metered house connections.(Leta et al., 2015).

Though leakage is one of the main causes of water loss in the delivery system of networks, the loss of water through illegal connections and non-functioning meters also contributes a lot; this requires a proper system of management and monitoring(Leta et al., 2015).

The global amount of non-revenue water (NRW) is becoming unpredictable, according to the World Bank Report (2005). Over 32 billion m3 of treated water was lost each year by leaks from distribution networks (Liemberger & Wyatt, 2019). An additional 16 billion m^3 per year are delivered to customers due to theft, poor metering, or corruption, but not charged.US$14 billion is a conservative estimate of the average annual expense of water utilities worldwide. This loss represents 50-60 percent of the water supplied in some low-income countries, with an approximate global average of 35 percent, saving just half of this amount will provide water to an additional 100 million people without further expenditure.(Araral, 2009).

The mean unaccounted-for water (UFW) in the developing world showed the higher rate of water losses (Access, 2020). Any reduction in water losses would not only take consistent action to fix them. It is important to be more active and engage in other organizations or states, corporations, and the general community. In third world countries, including Ethiopia, the issue of water losses and leakages is getting worse.(Liemberger & Wyatt, 2019) .

While developed cities have begun to use online continuous operation and monitoring systems, it is very difficult for developing cities to even gather information on their past operation and maintenance activities that could help them establish a potential strategy. To determine the efficiency of the system and to identify the location and magnitude of water losses, many developed nations use water audit procedures.

1.2. Statement of the Problem

Simple metal salts are the most widely used coagulants. The three main coagulants in this group are aluminum sulfate, ferric sulfate and ferric chloride. These chemicals can be bought in bulk for larger plants or in bagged form for smaller systems or in solution form. The benefit of this category is that it is typically the lowest cost for care. That is why this community is used extensively by the bigger plants. This group's disadvantages include the need for pH adjustment for more additional chemicals (usually lime, sodium hydroxide and/or soda ash) and the need for more operator control/attention/time to adjust feed rates due to changing turbidity of raw water quality(Gorecki et al., 2009).

In many towns of Ethiopia, especially in Gambella town, an intermittent supply of water is common. It can lead to a spiral of decline, as system management is extremely difficult and the willingness of the customer to pay declines. Water demand for household purposes has increased as a result of population growth and rising living standards, as well as progressive environmental degradation issues, resulting in overuse of renewable drinking water sources and deterioration of water quality.

The research is on the assessments of efficiency of Aluminum sulfate & Okra seed coagulants in Gambella town. Aluminum sulfate is very expensive, and people's ability to pay for services is limited. Skills and technology are also scarce. As a result, locally available materials can be used to achieve a long-term safe water supply.

1.3. Objectives of study

1.3.1. General Objective

The main objective of this research work is to investigate the efficiency of Aluminum sulfate and Okra seed coagulants for drinking water treatment in the case of Gambella town.

1.3.2. Specific objectives

1. To conduct experiment on Okra for wastewater treatment & removal efficiency.
2. To conduct experiment on Aluminum sulfate for wastewater treatment & removal efficiency.
3. To investigate the effect of operating parameters such as pH, Dosage & Time on the wastewater treatment using Okra.
4. To evaluate the coagulation capacity of Okra and Aluminum sulfate.

1.4. Research question

1. How to conduct experiment on Okra wastewater treatment & efficiency?
2. How to conduct experiment on Aluminum sulfate for wastewater treatment & efficiency?
3. How to investigate the effect of operating parameters such as pH, Dosage & Time on the wastewater treatment using Okra.
4. How to evaluate the coagulation capacity of Okra and Alum?

1.5. Significance of the Study

There is a lack of a water treatment laboratory in Gambella area, that's is why the main purpose of this study was used to investigate that we use locally accessible Okra seeds to treat low turbid wastewater, which is both ecologically friendly and economically effective, as well as naturally available & compared with Alum. The study can also bridge to the current gap in research and help prepare or replicate the findings for sustainable urban water supply growth. It is, therefore, important to investigate the water supply treatment capacity.

The use of natural materials of a plant for wastewater treatment has been adopted. However, lack of enough knowledge on the exact nature and mechanism on how these impurities in water make them less likely to compete with conventional treatment. Using such natural ingredient is important because natural compound that has significant application and plays role in water treatment processes and it is degradable.

The goal of this study is to provide an insight in to the utilization of Okra seed materials as an alternative natural coagulant for wastewater purification as well as coagulation mechanism (coagulation activity assay). The reason why I choose this title is to meet the motto of Jimma University (**we are with the community**) and the result was most probably effective.

1.6. Scope of the study

For the analysis, a sample was acquired from Gambella Town, Baro River. The results of experimental parameters such as Color Removal, Turbidity & TDS were studied, response surface methodology (RSM) analyses the laboratory result and optimum value was selected. In order to complete the analysis, which was limited by the material & equipment available as well as time & budget was considered.

CHAPTER TWO

Literature review

2.1 Chemical coagulation

The method of destabilizing colloidal impurities in water or wastewater by using chemically generated substances is chemical coagulation. The process of flocculation on charge neutralization is referred to as flocculation(Hamawand., 2015). For water and wastewater treatment, aluminum sulfate, potassium aluminum sulfate, iron (III) chloride hexahydrate, ferric sulfate, etc. can be used as coagulants. Alum is the chemical coagulant that is most widely used. Alum contains potassium and aluminum, and is described chemically as KAl $(SO4)_2.12H_2O$(*Quintero-Jaramillo et Al., 2016*).

Alum or potassium aluminum sulfate is very frequently used for water and wastewater treatment. Alum is easily available and is an inexpensive alternative for the wastewater treatment. Used alum for treating wastewater from the metal fabrication industry. Alum, at a concentration of 450mg/L, removed 99% of color from the wastewater at a pH of8.0(Aravindan et al., 2014). By using it with other coagulants, the potency of alum may be improved. In a study, when used with polyacrylamide (PAA) and poly ferric sulfate (PFS), alum resulted in an improvement in COD removal efficiency to 82% from 68% to 82%.(Access., 2020).

The potential of ferrate salts for the treatment of wastewater and its potential application for the treatment of wastewater have been documented. Iron (III) chloride can also be used as a coagulant for wastewater treatment, also referred to as ferric chloride (represented as FeCl3).(Bogacki et al., 2011)Ferric chloride has been used for the disposal of wastewater in the cosmetic industry in order to minimize COD. Using ferric chloride, a COD reduction of up to 63.9 percent at a pH of 6.0.0 was achieved. It is also possible to use poly aluminum ferric chloride as a coagulant(Mobasherpour et al., 2014). To treat the molasses wastewater, ferric chloride was used. 96 percent color and 86 percent COD could be separated from the wastewater under ideal conditions. (YANG et al., 2009).

For the removal of 93 percent orthophosphate from aquaculture discharge, ferric chloride was used. Iron (II) sulfate can serve as a coagulating agent for waste water treatment, often referred to as ferrous sulfate (represented as $FeSO_4 \cdot xH_2O$).In a comparative study of lime, alum, ferric chloride ($FeCl_3$), ferrous sulfate ($FeSO_4$) and magnesium chloride ($MgCl_3$) coagulants for the treatment of waste water from the textile industry,(Razmkhah, 2007)It was found that ferrous sulfate was the most effective and, at low coagulant dosage, could remove color, had minimum settled sludge volume and maximum wastewater depolarization. A comparative analysis of alum and ferric sulfate from the milk industry for the disposal of wastewater. Up to 95% turbidity and 62%, COD could be extracted by ferric sulfate. (Loloei et al., 2014).

Aluminum sulfate is an aluminum salt, which can be used for wastewater treatment as a coagulant. For wastewater treatment, poly aluminum chloride (PAC) may be used as a coagulant.(Liaquat et al., 2013)For automotive wastewater treatment, poly aluminum chloride was used and stated that it could extract 98 percent iron, 83 percent zinc and 63 percent nickel. After immobilization, chemical coagulants were found to be more efficient compared to their native forms in reducing TDS, phenolphthalein, complete phenolphthalein, COD, and chromium.(Biert et al., 2016). Immobilized ammonium aluminum sulfate has been found to be more effective in removing chromium from wastewater from the tannery industry. (Biert et al., 2012). The neutralization of the charge by hydrolyzing metal coagulants and the effects of precipitated metal hydroxide.

The basic principles of colloid stability and metal ion hydrolysis were also examined in the report. PACAC is one of the hydrolyzing salts that can be used as coagulants to help the coagulation and flocculation process.(*Journal of Materials Chemistry B (RSC Publishing)*, 2017), Poly ferric sulphate, poly aluminum ferric chloride, and. Even at a limited dose, they have superior color removal efficiency and are efficient for waste water treatment across a wide pH range.(Wei et al., 2018)To extract phosphorus from synthetic wastewater treated using 0.2 g/L of kaolin solution, poly ferric acetate was used. It was found that the removal percentage of phosphorus was 96.1 percent using poly ferric acetate under the optimum pH range of 7.0-9.0, showing it to be a promising alternative to phosphorus removal from wastewater. Chemical coagulants for the disposal of black liquor waste water, such as aluminum chloride, poly-aluminum chloride and anionic PAM (Rathod et al., 2017).

The combination could eliminate 88 percent color, 95 percent total suspended solids and 81 percent COD. A modern approach to wastewater treatment is the response surface methodology (RSM). To evaluate the efficiency of coagulants in the coagulation and flocculation process, this technique uses a combination of mathematical and statistical models.(Prakash Maran et al., 2014)used this technique for the bagasse wastewater treatment with the help of biopolymer. (Fu & Wang, 2011) used aluminum chloride for paper mill wastewater treatment as a chemical coagulant. Furthermore, as a flocculant, a modified natural polymer was used. The models were designed to achieve the turbidity, lignin removal efficiency of chemical coagulants. The coagulant dose used for the experiments was 871 mg/L, and a flocculant dose of 22.3 mg/L at pH 8.35 was chosen to help the operation. Experiments have shown that the combination of Uniform Design and RSM offers a successful solution to wastewater treatment for paper and pulp mills.(Ghafari et al., 2009)The performance of poly aluminum chloride and alum for leachate treatment has been investigated. Quadratic models were developed using Central Composite Design (CCD) and Response Surface Method (RSM). The efficiency of the coagulants was determined using 2 g/L PAC (at a pH of 7.5) and 9.5 g/L alum. The estimated efficiency of the coagulants was consistent with the test results.

The removal efficiencies of COD, turbidity, color, and TSS for PAC were stated to be 43.1 percent, 94.0 percent, 90.7 percent, and 92.2 percent, respectively. Alum's equivalent efficiencies were found to be 62.8%, 88.4%, 86.4% and 90.1%, respectively. There are some benefits of chemical coagulants. Fast availability and inexpensive costs are some of the factors that overshadow the challenges and issues associated with the large-scale industrial application of these coagulants. As they are efficient over a broad pH spectrum, the performance of chemical coagulants is not affected by the pH variation. At very low dosages, the optimal conditions are obtained. The simple availability of chemicals, ease of storage, no loss of long-term storage performance, device reliability and improved efficiency are some of the main benefits of chemical coagulants. (Semerjian et al., 2003). Several distinct variables affect the efficacy of the chemical coagulant. The factors influencing the efficacy of chemical coagulants will be comprehensively detailed in the next section.

2.1.2 Factors affecting the efficiency of chemical coagulants

Wastewater properties, form and volume of coagulant used are the factors influencing the efficiency of the coagulation process. (Alhomidi & Reed., 2013). Temperature also has a very important impact on the flocculation process. The effect of temperature on the effectiveness of coagulants to flocculate. The study reported that the flocculation efficiency is reduced at lower temperatures as the larger flocs get broken.(Joudah, 2014). Warmer temperatures are therefore, preferred to ensure better flocculation (Brignole et al., 2004). The efficacy of coagulants in the treatment of wastewater depends on the pH of the wastewater.

The effects of pH, temperature and stirring rate on the coagulation and flocculation performance of four coagulants have been comprehensively studied: alum, ferrous sulfate, ferric chloride and commercial synthetic cationic polymer (Altaher et al., n.d.). The study stated that the pH of wastewater greatly influenced the reduction in turbidity. At greater pH values, the highest removal efficiency was obtained.

The variation in the rate of stirring did not affect the efficiency of coagulation. The coagulation process has been described as an efficient method for wastewater treatment with variations in temperature, dosage, and concentration. (Qu et al., 2018). For the treatment of low temperature and low turbidity water, a mixture of poly aluminum chloride and chitosan is used. This coagulant mixture yielded turbidity, DOC and UV254 removal efficiencies of approximately 87%, 63%, and 82%, respectively. In another study,(Ramakumar et al., 2017)It was noted that the natural coagulant Plantago ovata (P. ovata) performed best at room temperature and removal efficiencies ranging from 98.2% to 80.2% were obtained when checked for varying turbidity values. PO-NaCl was, however, found to be most effective in alkaline circumstances. In all the pH variations and dosages, various combinations of natural and synthetic coagulants for water treatment and turbidity removal of 99.29 percent were achieved. The effect of parameters such as temperature, dosage and concentration of the source water on the coagulant dosage and efficiency should therefore be taken into account.(Deeraj et al., 2020).

2.1.3 Addition of flocculants

With the addition of flocculants, the efficacy of the chemical coagulants can be further increased. Flocculants are the substances that bind destabilized particles, allowing colloidal impurities to settle in the form of flocs.(Godos et al., 2011). In order to determine their efficiency of algal biomass removal from piggery wastewater, Fe_2 $(SO4)_3$, FeCl3 and five industrial polymeric flocculants (Chitosan, Flocudex CS/5000, Drewfloc 447, Flocusol CM/78, and Chemifloc CV/300) were used. The combination of 150–250 mg/L ferric salts and 25–50 mg/L flocculants achieved biomass removals of up to 98 percent. Vanerkar*et al.* 2013 Uses the coagulation and flocculation technique, the food industry treated wastewater and addressed the actions of coagulants supplemented with polyelectrolytes. In order to obtain the best performance, various coagulants and flocculants were tried and lime was chosen as the ideal coagulant based on the cost factor. Lime was used for coagulation and, at a dose of 200 mg/L, resulted in 53.59 percent COD and 57.19 percent BOD reductions, respectively. At this dose of the coagulant, only 25 mL/L of sludge was produced. For the procedure, the dosage of alum was not very successful. In combination with 200 mg/L of lime, Magnafloc E-207 effectively reduced 67.61 percent, 71.01 percent and 81.53 percent of COD, BOD and SS, respectively, by 0.3 mg/L.(*Vanerkar et Al., 2013*). anionic and cationic polyacrylamides to treat paper and pulp mill wastewater.(*Aguilar*, 2005)Anionic polyacrylamide has also been used to enhance the coagulation-flocculation process for slaughterhouse effluent therapy. The use of anionic polyacrylamide has helped to increase the coagulation performance of the coagulants and, eventually, to minimize treatment costs. In order to get zero discharge, chemical coagulants have also been used in combination with other methods. El-Awady*et al.*, 2019 studied the possibility of reusing treated water from a paper recycling mill industry to obtain zero discharge from the unit.

The treatment of wastewater was conducted using synthetic coagulants such as alum, ferric chloride and cationic polymer. Removal efficiency was achieved for TSS at up to 98.9 percent and for COD at up to 79.4 percent. It was noted that the treated water was appropriate for re-use in the industrial activities unit..(Mohammadtabar et al., 2019)In combination with coagulation, five chemical membrane hybrid processes were tested for the treatment of boiler blow-down water from oil and sand streams. This experimental study showed that up to 97 percent of TDS elimination resulted from the direct treatment of blowdown water by nano-filtration A 97 percent flux recovery was achieved by simple hydraulic washing that required the need for pre-treatment with wastewater and soda ash solutions for ion exchanger regeneration.

These two combined processes can help achieve zero liquid discharge and sludge-extracted calcium sulfate has direct applications in cement manufacturing, food factories, and water treatment, while nano filter soda ash can be reused for ion exchanger generation.(Semblante et al., 2018) tried to find better brine management solutions and recommended coagulation and flocculation phase pre-treatment accompanied by thermal treatment to achieve a Zero liquid discharge pre-treatment.

2.1.4 Disadvantages of chemical coagulants: Health and environmental impacts

Using synthetic chemical coagulants, chemical coagulation is carried out. This practice has the potential to have a detrimental effect on the environment and public health. Even after the coagulation process is completed, chemical coagulants are non-biodegradable and remain in the water. There is a possibility that the treated supernatant contains the traces of metals present in the chemical coagulants due to the presence of residual aluminum in the supernatant(J et al., 2017). Use of chemical coagulants can cause neurological diseases like Alzheimer's disease(Lautenschlager et al., 2010), Encephalopathy leading to dementia, Down's syndrome and staining of Hippocampal neurons(Roberts et al., 2006). The treated water containing the high concentration of residual aluminums may either get seeped into the groundwater or may have a surface runoff(Murphy et al., 2010).

Chemical coagulants are non-biodegradable(Muralimohan et al., 2014) and remain in the water because of which, synthetic chemicals are said to generate a sludge that may not be amenable to safe environmental disposal and may result in contamination of our water and land. In his study suggested that supernatant obtained from dairy industry using alum and ferrous sulfate was not suitable for discharge into the municipal drains due to the high values of various parameters like BOD and COD in the supernatant. Major issues with the use of aluminum-based coagulants are that they lead to increased concentration of residual aluminum in the supernatant. This aluminum may either seep into the groundwater or may have a surface runoff(Murphy et al., 2010). Conventional, water and wastewater treatment plants do not remove aluminum and water with elevated aluminum content(Roberts et al., 2006) is supplied to the end consumers.

If aluminum entered the public distribution system, it could lead to precipitation of hydrous aluminum in the water, which is to be supplied to the consumers. Residual aluminum in the treated water is found to negatively impact the health of consumers. Exposure to aluminum is linked to Alzheimer's disease(Lautenschlager et al., 2010) as it stains the Hippocampal neurons). Aluminum is neurotoxic and is responsible for disorders like Parkinson's disease and Down's syndrome (*Golden Arches East: McDonald's in East Asia, Second Edition - Google Books*, n.d.). Its accumulation in the bloodstream for the long term can result in severe Encephalopathy, and consequently contributing to dementia(Shultz et al., 2004).

2.2 Natural coagulant for wastewater treatment

The possible environmental and human health risks associated with the use of chemical coagulants have necessitated the need for industrial wastewater treatment to use natural coagulants. These days, natural coagulants are attracting a lot of attention as they are successful Alternative to coagulants with chemical compounds (Amran et al., 2018).

Plant-based materials have been investigated for treating industrial effluents from different industries. Plant-based substances like *Moringa Oleifera*(Gautam & Saini, 2020), chitosan and chitin, *Abelmoschus esculentus*, *Opuntia Ficus-indica*, *Synchronous Potato rum*, *Prosopis laevigata* Seed Gum, *Hibiscus rosa-sinensis*(Awang & Aziz, 2012), *Acacia mearnsii*(Beltrán-Heredia et al., 2011), etc. can be used as coagulants. Generally, the natural coagulants are directly used as a powder or a stock solution.

In some cases, the deoiled powder is also used, after extraction of oil from the coagulant. The plant-based products (such as seeds, etc.) are first extracted from the plant, cleaned to remove any impurities that may interfere with coagulation, and then dried. The powder is then formed (with or without the oil extraction, as per need) by grinding(Maeder et al., 2008). This powder may be directly used, or a stock solution can be prepared from it. In some cases, proteins may be extracted from the specific plant parts and used as a coagulant. This may require extensive extraction and purification steps (Kansal & Kumari, 2014).(Maeder et al., 2008)reported that the microbial polysaccharides, starches, gelatin galactomannans, cellulose derivatives, chitosan, glues, and alginate can be used for wastewater treatment.

Natural coagulants can also be used with synthetic coagulants to assist the coagulation process for wastewater treatment(J et al., 2017).*Moringa oleifera* and *Strychnospotatorum* seeds as a natural coagulant for car wash wastewater. The turbidity and COD reduction efficiency of coagulants was studied. Using *Moringa oleifera*, 94%turbidity, 60% COD, 81% phosphorus removal were obtained, whereas using *Strychnospotatorum*, 97%turbidity, 54% COD, and 82% phosphorus removal were obtained.

These results were compared with synthetic coagulants, and natural coagulants were suggested for coagulation process as they provide better treatment, are cost-effective and are safe for environment. The feasibility of natural coagulant for the treatment of dairy wastewater. *Artocarpusheterophylius*(jackfruit) and *Phaseolus vulgaris* (Common Beans) were used to remove turbidity from wastewater. *Artocarpusheterophylius*(jack fruit) seeds attained94% turbidity removal efficiency and Phaseolusvulgaris (common beans) seeds gave up to 99% of turbidity removal (*Sundaresan and Anu, 2016 - Google Scholar*, n.d.). The grape seed for removal of cationic dyes and confirmed that grape seed-derived coagulants induced decolorization of cationic dyes (K. Jeon et al., 2009). Derivatives of *Opuntiaficus-indica*for treatment of the wastewater. The study demonstrated coagulant as a very promising alternative to remove dyes, metallic species, heavy metals, turbidity and COD(Nharingo & Moyo, 2016).

Plant-based polyelectrolytes as coagulants (derived from the fruits of *Opuntia ficusindica*, fruits of *Jatropha gossypifolia* and *Borassusflabellifier*) to remove chromium(Huang et al., 2013).

It was concluded that there isa significant improvement in the physicochemical characteristics of wastewater and heavy metal chromium was successfully controlled by natural coagulants. These polyelectrolytes can be effectively used for removal of chromium as they destabilize and reduced the repulsive forces between the molecules. the common bean for distillery wastewater treatment and it was concluded that pH value of stillage influenced activity of the natural coagulant(Freitas et al., 2015). The optimum pH for the treatment was reported to be 8.5. Saharudin and Nithyanandam2014 assessed possibility of using natural coagulants as an alternative to the aluminum sulphate and to optimize the parameters related to the working for treatment of synthetic wastewater samples. It was concluded that roselle seeds are a viable commercial alternative to aluminum sulfate. The highest removal efficiency with roselle seeds powder was within the range 81.2% to 93.13% for synthetic wastewater at a pH 4.0. However, the highest removal efficiency for industrial wastewater was within 76.8% to87.18% at a pH value of 10.0. Banana pith juice for textile wastewater treatment. At pH 4, 97.5%turbidity and 50.1% total solids were removed from the wastewater(Liatis et al., 2016). There was a significant improvement in the electrical conductivity. The results confirmed that banana stem juice has an enormous potential for turbidity removal from the textile wastewater. Wu*et al.* 2005 used white-rot fungi for degradation of lignin from the paper mill wastewater. The lignin and COD removal efficiencies were reported to be 71%and 48%, respectively. Optimum pH range for lignin removal by *Chrysosporium, Pleurotusostreatus*andwas observed to be 9.0-11.0.

Gaurang and Punita2012 used fruit mucilages of *Cocciniaindica*and*Abelmoschus esculentus*, and the dry seed powder of Moringa for treatment of dairy wastewater. Using *Abelmoschus esculentus*, 60.33% of turbidity could be removed whereas *C. indica*gave highest turbidity removal of 77.67%. Nicholas *et al.* 2018 used *Hibiscussabdariffa*seeds for removing dyes from the synthetic wastewater.

The study involved preparation of models and ANOVA (analysis of variance). Response surface methodology showed 98.68% dyes removal from the wastewater. Oyster mushroom has been tested for the reduction of parameters like turbidity and TSS (total suspended solids) from domestic wastewater. The basic coagulation mechanism of natural coagulants differs from that of the synthetic coagulants due to their inability in forming the hydroxide precipitates in the water. Synthetic coagulants generally work on the mechanism of charge destabilization and sweep flocculation. In comparison, the polymeric nature of plant-based coagulants and presence of functional groups suggest that polymer bridging, and charge neutralization are the dominant mechanism for the natural coagulants (Ang & Mohammad, 2020). For some of the natural coagulants, adsorption in conjunction with either charge neutralization or polymer bridging has been cited as the dominant coagulation mechanism(Kukić et al., 2015).*Commonly studied natural coagulants.* A large number of natural coagulants, mostly plant-based, have been studied for their potential in treating industrial effluents. A brief description of some of the more commonly studied coagulants is provided here. *Moringa Oleifera* is a small or medium-sized tree grown in northwest India, several parts of Asia, Africa, and South America. It is a multipurpose plant(Muthuraman & Sasikala, 2014) is cultivated in tropical, sub-tropical or semi-arid regions at an altitude between 0-2000 m. Cultivation of *Moringa* requires an annual rainfall between 250-3000 mm. It belongs to the *Moringaceae*family(Okuda et al., 2001). Moringa can grow on the low altitude tropical belt on the less humid soil. *Moringa Oleifera* is an organic polymer. Moringa grows rapidly from the seed or cutting and does well even in poor soils (*African Journal of Traditional, Complementary and Alternative Medicines,* Adebayo *et al.,* 2017). *Moringa oleifera* is one of the most effective and certainly the most investigated natural coagulant for wastewater treatment (Bhuptawat et al., 2007). Typically, the grounded seed powder of *Moringa oleifera* is used as a coagulant. (Sulaiman et al., 2017) studied the potential of *Moringa* and reported excellent results for wastewater treatment. The seeds of moringa do not further deteriorate the environment and are amenable to biodegradation and thus are environment friendly.(Hemapriya *et al.* 2015) used *Moringa* for treating the textile mill effluent. *Moringa oleifera* was reported to cause significant COD reduction for textile mill wastewater(Dotto et al., 2019). (Parmar *et al.* 2012) used grounded seed powder of *Moringa Oleifera* for dairy wastewater treatment. The *Moringa oleifera* seeds left the water clear and reduced the turbidity by almost 100 percent and 99.50-100 percent removal of fecal coliforms was observed. Ashmawy *et al.* 2012 used *Moringa Oleifera* for treating the laundry wastewater and obtained up to 83.63% of turbidity removal.

2.2.1 Advantages of natural coagulants

Wastewater treatment using natural coagulants is an eco-friendly option. Natural coagulants are non-toxic, biodegradable, and environment friendly (EH et al., 2018). Unlike synthetic coagulants, treated water contains no residual aluminum. (Prodanović*et al.* 2013) used common bean extract for the treatment of distillery wastewater treatment.

The study claimed that anaerobic sludge contained no aluminum salts. This ensures that aluminum-related health issues (such as Parkinson’s disease, Alzheimer’s disease, and other neurological diseases), as stated earlier, would be absent when natural coagulants are used for the coagulation-flocculation of the wastewater. The supernatant and sludge produced on treatment using natural coagulants can be used for other purposes, unlike those obtained from chemical coagulation(EH et al., 2018).

2.2.2 Disadvantages of natural coagulants

A major drawback of using natural coagulants is their inability to manage large pH variation. Most of the coagulants work well under certain pH, beyond this range, their efficiency is severely affected.(Krivova et al., 2010) used *Moringa Oleifera* for dairy wastewater treatment. The results demonstrated that the adsorption power of *Moringa Oleifera* seeds was best in the pH range of 5 - 8. Natural coagulants for the treatment of the food industry effluent in place of ferric chloride. Although the supernatant contained no traces of metal, Chitosan was found to be less efficient as its dilution occurs best at acidic pH. This may increase the cost of wastewater treatment using chitosan(Cosman et al., 2016).

Natural coagulants contain organic matter and therefore the efficiency of these coagulants may decrease over time. Proper arrangements are required to store these coagulants in stock. This will increase the overall cost of the treatment. Another drawback of using natural coagulants for wastewater treatment is the requirement of high dosages as compared to the synthetic coagulants (Aliyu & Ramli, 2015). Used moringa and *Abelmoschus esculentus* for the treatment of the water from River Yamuna, India. Results showed that for treating the water from the same source, 150 mg/L to 200 mg/L of moringa and *Abelmoschus esculentus* were required, whereas better results were obtained using alum at a much lower dose of 30 mg/L under the same experimental conditions. In a comparative study between alum and natural coagulant *Moringa* for treatment of dairy industry wastewater, it was found that alum had better efficiency as compared to *Moringa oleifera*(Rizwan et al., 2017).

2.2.3 Okra (lady finger or bhindi)

Okra (gumbo) is already an important vegetable crop grown in tropical and subtropics parts of the world. The okra seeds are used for the treatment of water sample. For the water treatment, the oil contained in the okra seeds was first extracted, before the okra seeds used. In the range of studied, it is observed that whatever the volume of gumbo mucilage, the turbidity decreases when the pH increases(Jatav et al., 2016).

Figure 1 Okra seed

2.3 Issues in the large-scale implementation of natural coagulants

Natural coagulants for wastewater treatment are an inexpensive and environmentally safe alternative to synthetic chemicals. Despite the tremendous potential, treatment of natural coagulants is challenging, and so far, the use of natural coagulants has been limited to laboratory scale studies. Some of the issues preventing the large-scale application of natural coagulants for wastewater treatment are:

2.3.1 Competitiveness

Many natural coagulants have a number of applications and their use in the treatment of wastewater will affect the availability for other uses of these coagulants. Moringa oleifera is used to treat various illnesses, such as asthma, syphilis, asthma, etc.(Kasolo et al., 2010). Because of the multipurpose uses of the Okra plant, the use of okra for wastewater treatment often has different consequences. For example, okra is consumed in Western Africa and Southeast Asia as a vegetable. As a fire, dried okra stems are used as it burns significantly and Generates substantial heat (Ojo et al., 2014). *Okra* mucilage is used for manufacturing paper in Malaysia investigated the chemistry, properties, and applications of chitin and chitosan. In various other areas, such as agriculture, cosmetics, photography, chromatographic separations, solid state batteries, biomedical applications, burn care, wound healing/wound dressing, artificial skin, ophthalmology, drug delivery system, and LED (light-emitting devices) applications, chitin and chitosan have also been used.(Yadav et al., 2018).

A non-competitive coagulant needs to be detected to ensure the large-scale application of natural coagulant. Moreover, for their coagulation ability, plant-based materials that are otherwise considered waste can also be investigated. A widely used vegetable and source of Petha candy is Benincasahispida, commonly known as ash gourd (a common sweet popular in Indian sub-continent). Its seed is usually discarded. The seed powder of *Benincasa Hispida*has recently been studied for its coagulation potential for the treatment of river water (Saini et al., 2017).

2.3.2 The absence of source for mass availability

Not all of the natural coagulants mentioned in this study are widely available and it raises questions about the continuous mass-scale supply that would be needed for commercial applications. The same natural coagulant can be more costly relative to synthetic coagulants in certain areas of the world due to the non-uniform distribution of plants.(Gautam & Saini, 2020).Chemical coagulants, on the other hand, can be generated and supplied as needed in industries practically anywhere. The application of locally sourced natural coagulants is a potential solution.

2.3.3 Potency losses

Organic matter is contained by natural coagulants and can decay over time. The efficacy of coagulants in the treatment of wastewater can be impaired by this decay. Potency loss studies are non-existent and are needed to assess the potential for natural coagulant losses of potency.(Freitas et al., 2015) studied the possibility of potency losses with the use of cactus. The effects of storage time and temperature on the coagulation ability of Opuntia ficus-indica have been investigated. The analysis showed that the efficiency had no effect for up to 4 days.(Freitas et al., 2015) . However, no other studies are available that have explored the ability of natural coagulants beyond 4 days or ways to enhance their shelf life. In evaluating and extending the shelf life of natural coagulants, further research is required.

2.3.4 High quantity requirement

In the case of natural coagulants, the optimum dosage is very high for the treatment of the same quantity of wastewater with the same values of different parameters compared to chemical coagulants. This implies that, compared to natural coagulants, waste water can be treated with a very small amount of chemical coagulants.(Omar et al., 2008)used sago and potato flour for COD reduction from semiconductor wastewater. Poly aluminum chloride and aluminum sulfate coagulants were also used.

The researchers found that at a low dose of 1.5 g L−1, sago helped reduce COD and turbidity. On the other hand, the use of poly aluminum chloride and ammonium sulphate at much lower concentrations (0.02-1.0 g L-1) showed significant reductions in COD and turbidity, although a much longer settling time of 30 to 60 min was required.(Omar et al., 2008).

2.3.5 High inventory and processing cost

As compared to chemical coagulants, natural coagulants are likely to have high inventory and production costs because of their biodegradable existence. Some arrangements will also be necessary for storing the natural coagulants in stock for later use.

2.3.6 Lack of awareness, market interest, and guidelines

The general public and service boards are currently not aware of the adverse effects of synthetic coagulants and the availability of natural coagulants as an environmentally sustainable alternative to synthetic coagulants. Due to economic uncertainty, utility services and plant operators are less likely to opt for a new technology esp. when there are more aspects of the natural coagulants that require thorough analysis. There are no standard guidelines available relating to the production, storage and use of natural coagulants. To encourage the commercial adoption of natural coagulants, all of these must be taken care of.

Table 1. Advantages and Disadvantages of Various Coagulation Chemicals

CHEMICAL	ADVANTAGES	DISADVANTAGES
ferric chloride or ferric sulphate	- best removal of organics - low cost - doesn't add aluminum to water - high iron residual is easy to detect	- improper doses cause reddish color and high iron residual - high iron residuals can plug filters and stain laundry - very acidic (full protective gear should beworn) - aesthetically unpleasing sludge (brown)
aluminum sulphate	- relatively low cost - less acidic (protective gear is stillrecommended)	- lower DOC removal - improper doses cause highaluminum residuals and may pose ahealth risk
polyaluminum chloride	- lower aluminum residual thanaluminum sulphate - less impact on pH and alkalinity	- cost is three times greater than that ofother coagulants
PAC (coagulant aid)	- improves removal of DOC - improves taste and odor	- should only be used in coagulation cells - costly

2.4 Water treatment with natural coagulants

The handling and treatment of waste water is a very major concern as the urban population increases day by day and the sources of pure water are used to contaminate by the direct pouring of untreated water(J et al., 2017). Therefore, treatment of water is very necessary before mixing any wastewater into the natural water resources. Biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and total dissolved solids (TDS), dissolved oxygen (DO), temperature and pH are the main parameters that indicate the quality of the water. Wastewater is the main contributor to water contamination among the various forms of wastewater municipal and dairy. Municipal wastewater is characterized as community-derived wastewater; it may consist of domestic wastewater and/or industrial discharge. Municipal waste water is high in BOD, COD, and less in DO etc..(Subramonian et al., 2014).It explained that dairy wastewater consists of high organic matter, mainly lactose, fat, and protein, particularly cheese whey. The organic content present in milk wastewater decomposes rapidly, thereby reducing the dissolved oxygen content of the discharge stream. It also produces a very bad odor. Also,(Shete et al., 2013)The receiving stream of dairy waste water is said to be the breeding ground for flies and mosquitoes that spread malaria and other dangerous diseases in the community. It is also recorded that fish and other marine animals are also harmed by this water. So, before mixing in the fresh water supplies, there is a definite need for milk wastewater treatment. Coagulation is a very traditional process for separating from the wastewater the suspended solids. Alum is a universally used coagulant, but due to the acidic nature of Al+3, the addition of alum to wastewater reduces the pH of waste water. The addition of chemicals also raises the cost of treatment, so it is important to provide a coagulant that during treatment does not affect the chemical properties of wastewater and has a very low cost. Several forms of research have been conducted to treat wastewater using natural coagulants. the initial turbidity was removed by Moringa oleifera seeds.(Mohagheghian et al., 2017) were also found the Moringa oleifera is very effective coagulant for the removal of BOD, COD, and TDS. In this study, the two natural and chemical coagulants, Okra, and aluminum sulphate (Alum) were compared for the treatment of municipal and wastewater.

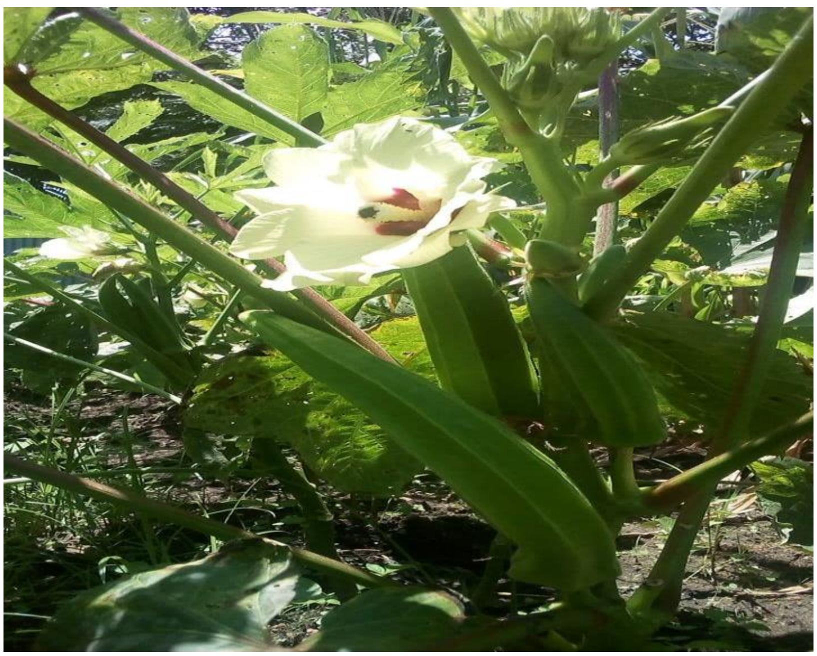

Figure 2 Okra plant on flowering date.

2.4.1 Health Benefits of Eating Okra

Okra or commonly known as lady's finger is a widely consumed vegetable in tropical regions. Okra is one of the most versatile foods, which are loved and consumed by all. It is biologically categorized as a fruit, but is generally consumed as a vegetable. A lot of people dislike the cooking procedure of this flowering plant due to its sticky texture.

But nevertheless, the delicious taste of any okra dish makes it all for the efforts. Okra is loaded with nutrients, which can be really beneficial for your health. This green veggie is filled with folic acid, vitamin B, vitamin C, vitamin A, vitamin K, calcium, fiber, potassium, antioxidants, and some vital phytonutrient. Keep scrolling to find out the importance of consuming okra on a daily basis(*J et al*., 2017).

2.4.1.1 Promotes weight loss

Okra is a good source of fiber, which will not only improve your digestion, but will also keep you satiated for a long time, thus minimizing your food cravings. Apart from that it also loaded with essential nutrients that boosts your body's metabolism and strengthens your core muscles.

2.4.1.2 Good for diabetes

People with an elevated blood glucose level should definitely include okra in their daily diets. As okra is rich in fiber, it helps in improving insulin sensitivity and also aids in controlling and maintaining blood sugar levels in the body. Ladyfinger contains a substance called myricetin, which is known to improve and increase sugar absorption by muscles and thus, can help in lowering the high sugar level in the blood(*Ways That Okra Benefits Your Health Taste of Home.*, 2019.).

2.4.1.3 Lowers the risk of cardiovascular diseases

Okra is a good option for people who have cholesterol or any other heart ailment as the fiber present in this veggie will help in lowering the bad cholesterol level and promote good cholesterol in the body. Fibers modify the production of bile juice in the intestines, thus, lowering cholesterol levels in the blood. Apart from that okra is rich in magnesium and therefore, helps in maintaining and regulating your blood pressure level in the body.

2.4.1.4 Has anti-cancer properties

Okra has a protein called lectin which is linked with fighting breast cancer. It is also said that okra suppresses cancer cell growth and helps in preventing cancer. Folate is also an essential nutrient which helps in preventing the risk of various cancer.

2.4.1.5 Boosts digestion

Dietary fibers present in okra aids in effective digestion and improve bowel movement. Fibers are known to cure stomach ailments such as constipation, IBS and even indigestion.

2.4.1.6 Helps in achieving a healthy skin

Okra has a good number of antioxidants which not only reduces oxidative stress but also effectively eliminates free radicals present in the body. Antioxidant aids in reversing the skin damage and slows down the aging process, thus, giving you a youthful skin.

2.4.2 *Moringa oleifera* coagulant protein

The Moringa genus is a tropical plant belonging to the Moringaceae family, 14 species have been described to date and all have varying degrees of coagulant properties. Seed extracts of Moringa oleifera (MO), commonly called Moringa, and are the most extensively researched as a water treatment agent. Various parts of this plant, such as leaves, roots, seeds, bark and berries, have many beneficial qualities, such as anti-tumor, anti-inflammatory, antibacterial and antifungal activities, and are used in the indigenous system of medicine, particularly in South Asia, to treat various diseases. (Anwar & Rashid., 2007).

Mechanisms of action: The proposed coagulation property mechanism of MO protein is supposed to be that positively charged proteins bind through electrostatic interactions to part of the surface of negatively charged particles. This results in the formation of areas of the particulate surface that are negatively and positively charged.

Due to particle collision and neutralization, formation of flocs with a net-like structure take place. The poor performance of CEs in low turbid water could be explained by low rate of contacts between particles in such water.

2.4.2.1 Thermo-resistance of MO coagulant protein

The protein is found to be thermo-resistant and possess coagulation activity after 5hours of heat treatment at 95°C (Kebreab A. Ghebremichael et al., 2005). Since this property makes them less vulnerable to deterioration, being thermo-resistant can be seen as a requirement for natural coagulants. They would not be ideal if they were heat sensitive due to the high average temperatures (35-40 °C) in tropical countries.

2.4.2.2 Effect of MO against microorganisms

MO extract has flocculating properties towards bacteria (K. A. Ghebremichael et al., 2006) and bacteriostatic effect has been observed against several human pathogens. However, the inhibition of *Escherichia coli* growth was found to be transitory, with resumption of growth after 3–6 hours (Bukar et al., 2010). In addition, MO were able to reduce the number of the parasite *Schistosomamansoni* cercariae and helminth eggs(Sengupta et al., 2012). Due to its bacteriostatic effect and ability to clarify and decolorize water before SODIS treatment, Moringa extract has been suggested as a complement to solar water disinfection (SODIS) (Keogh et al., 2017).

2.4.2.3 Other natural coagulants

Coagulation activity has also been reported from other plant materials such as: Cactus (*Opuntia spp*.) (Miller et al., 2008), common bean(*Phaseolus vulgaris*red bean (*Phaseolus vulgaris sp.*), sugarmaize and red maize (*Zea mays sp.*) (Antov et al., 2010), chestnut and acorn. *Cactus latifaria* and seeds of *Prosopis juliflora Cassia angustifolia*(Šćiban et al., 2009), Grape seeds (J. R. Jeon et al., 2009), Nirmali seeds (*Strychnospotatorum*) (Babu & Chaudhuri, 2005), Further, a coagulant protein with a molecular mass of around 6.0 kDa, similar to that of MO, was identified in both *V. unguiculata* and *P. aculeate*(Kihampa et al., 2011).

Although many natural coagulants have been identified, due to cost and availability globally, most of them are not feasible, making them difficult to implement for water treatment. In addition, availability throughout the year is an important factor to take into account. Some of them compete with food crops or have no effect on microorganisms. This calls for a systematic study in order to identify other natural coagulants that might be more applicable for water treatment.

2.4.3 Mechanism of Natural Coagulant

There are mainly four types of mechanisms of coagulation, which are double layer compression, polymer bridging, neutralization of charge and coagulation of sweep. However, the possible coagulation mechanisms for plant-based natural coagulant coagulation are only polymer bridging and charge neutralization.(Kristianto, 2017). Polymer bridging is preceded by polymer adsorption, which is a process where long chain polymers attach itself to the colloidal particle's surface because of the affinity-ty present between them. Only some part of the polymers is attached to the particle while the unattached parts will form loops and tails.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

Gambella National Regional State was found in the southwestern part of Ethiopia between Oromia, South Sudan and SPNN. The city is the capital of Gambella regional state. The absolute location for the town has longitude and latitude 8º15'N and 34º35' E. This study was conducted in Gambella Town, Gambella is the historic home of the indigenous Anuak but in recent years including the five-ethnic group (Anuak, Nuer, Komo, Majang & Opo) almost all the region has fully covered by the Ethiopian society the so-called Nations and Nationalities and people of Ethiopia.

The region has warm temperature. Most of the time the temperature is within the range of 27 to 33^0C, but sometimes temperature as high as 45^0C and as low as 10^0C are recorded in March and January. The average annual rainfall of the region is within the range of 900 to 2100 mm. The town has an estimated population of 40,000. (*SITUATION ANALYSIS OF CHILDREN AND WOMEN: Gambella Region*, 2019).

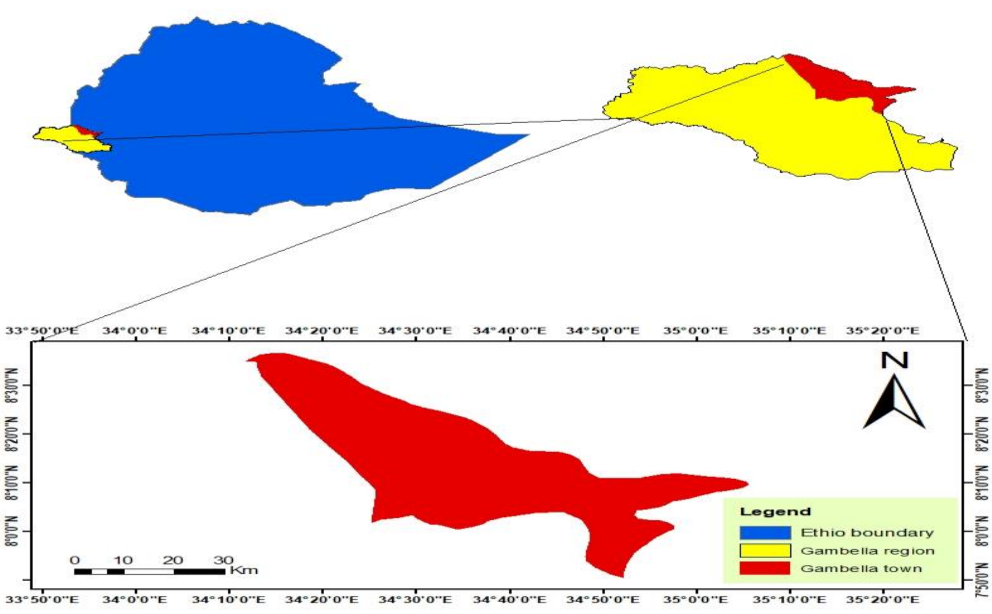

Figure 3. Geographical map of Gambella town.

3.1.2. Population

Western situated Gambella makes up a small region in terms of land mass and population. The region is sparsely populated, making up only 0.5 per cent of the total Ethiopian population (463,000 people). The Gambella population is young: 12 per cent is between zero and 4 years of age and 39 per cent is between 0 and 17 years of age. The fertility rate is one of the lowest in the country, with a total fertility rate of 3.5 (women, aged 15-49) but it is rising. In 2014, it stood at 3. The region is divided into three administrative zones (Anuak, Nuer and Majang), 12 woredas (districts) and one special woreda (Itang). The rural-urban divide is distinctive compared to the other regions of Ethiopia: 64 per cent of the population lives in rural areas and 36 per cent live in urban areas. Other regions have a much smaller urban population. The regional capital is also called Gambella, and is situated in the central part of the region. The federal government of Ethiopia has classified Gambella region as a Developing Regional State(*CSA 2007*)

3.2. Study variables

There are two types of variables namely dependent and independent variables.

3.3.1 Dependent variable

- ✓ Removal Efficiency (Color Removal, Turbidity Removal, TDS).

3.2.2 Independent variable

The independent variables that are to be measure and manipulate to determine its relationship to observe phenomena are select, those are,

- ❖ pH
- ❖ Dosage
- ❖ Time

3.3 Model of data analysis and presentation

Upon successful completion of the data collection, the data collected was analyzed and interpreted by using Microsoft excel & Response Surface Methodology (RSM) software. Its Optimization & analysis were done by using qualitative & quantitative data analysis method.

3.4 Ethical consideration

Ethical clearance to carry out the study was obligated from Jimma university Environmental Engineering ethical review committee. Data and sample collection were conducted after obligating informed consent from the concerned offices such as Gambella zuria woreda and Gambella town water supply offices. Study objectives can be clearly explained to administration offices, water supply offices and municipalities.

3.5 Data quality assurance

Proper quality assurance procedures and precautions were taken to ensure the reliability of the results. Samples were handled carefully and analyzed with in holding time to avoid physical and chemical changes occur to them. For the sake of data quality, assurance data is assessed carefully and triple entry of data is performed to assure quality of data.

3.6 Experimental work

Jar test were carried out to determine the coagulation properties of plant derived coagulants. One beaker was used as control and in other beakers varying dosage of coagulants was added. Jar test were conducted on 6 beakers with 100ml turbid water samples each, following that addition of the coagulant doses of okra seed were subjected to a rapid mixing at 150rpm for 5min and a slow mix step at 50rpm for 15min, the stirrer was then switched off and the flock allowed to settle undisturbed for 20min take the first reading, the second reading at 40min and the third reading was taken at 60min.

Figure 4. Jar test reading taking at different time.

I, Materials

The nearby market for vegetables has become the source of Okra. The okra seeds were used for the preparation of to extract the pH of the stock solution was regulated by sodium hydroxide and hydrochloric acid. Coagulant powder preparation has been clarified.(Singh & Srivastava., 2019).

II, Okra (ladyfinger or bhindi)

Okra commonly known as ladyfinger is one of the important vegetable crops grown in tropical and subtropical area of the world. First, the oil contained in the okra seeds is extracted and then used for waste water treatment.(Singh & Srivastava., 2019).

Figure 5 Okra seed

III, Water sample

The water sample was collected from the Baro River for testing (Gambella). The water sample collection was used within 1-2 weeks and the water sample was kept in the refrigerator at a temperature of approximately 2^0C. Two separate samples were obtained, with a volume of 25 liters, and the raw characteristics were reported.

IV, preparation of Coagulants

Okra seeds bought from the market were washed and sun dried for 24 hours. To obtain powdered shape and sieve to a mesh (500) μ particle size, such dried seeds were then grinded through pestle and mortar to extract the large particle size of the seeds. To form 1000ml of suspension, 10g of seed powder was mixed with 1000ml of distilled water. Using a clean magnetic stirrer for 5min to remove the component, the suspension was then thoroughly mixed. For 15 minutes of suspension, the solution was left untouched, then filtered to remove particles and dried the powder for 6-8 hours.(Singh & Srivastava., 2019).

V, Procedure

- Before testing, the physical and chemical properties of the sample, such as pH value, turbidity, TDS, were checked. All these experiments have been carried out using conventional methods.
- Using clarifloculators, the coagulation efficiency of the Okra seeds was tested and confirmed. In six parts, the Okra coagulant doses were sampled. For the jar test, 600ml of sample water was collected. The steps that followed were:
- In the water sample, the coagulant prepared was first mixed at different doses in the available six beakers and subsequently subjected to a jar test. The jar was subjected to rapid mixing for 5min at 150 rpm and then slow mixing for 20 min at 50 rpm.
- Thereafter, switched off the stirrer and allowed the flocks to settle without disturbing the beaker jars for 20min, 40min and 60min respectively to take the reading.
- The residual turbidity measurement samples were removed using a pipette 5 cm below the surface of each beaker and the residual turbidity was measured for each beaker sample. The turbidity removal efficiency was tested and compared with the standard values(Singh & Srivastava., 2019).

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Removal Efficiency of Okra for Wastewater Treatment

In this study the efficiency of okra seed coagulants has been tested in the following study. The efficiency was specified by the quantity of turbidity removal, confirming the efficient turbidity removal of Okra was 98.113% at pH3 and dosage of 0.5g & Alum was 99.8% at pH3 and dosage of 1.5g ranges at a volume of 500 ml.

Okra is one of the most versatile foods, which are loved and consumed by all. It is biologically categorized as a fruit, but is generally consumed as a vegetable and the byproduct (Okra seed) is also used to wastewater treatment in this thesis.

Table 2 percentage removal of Okra at different dose, time and pH.

Run	pH	Dosage (g)	Time (min)	%ge Color Removal	%ge Removal of TDS	%ge Removal of Turbidity
1	3	0.5	20	89.06	81.88	88.70
2	3	0.5	40	95.75	82.2	92.50
3	3	0.5	60	98.11	82.96	91.04
4	3	1.5	20	77.36	83.32	68.13
5	3	1.5	40	88.02	84.16	68.50
6	3	1.5	60	86.41	83.92	66.32
7	3	2.5	20	73.02	86.88	46.95
8	3	2.5	40	65.09	83.24	30.83
9	3	2.5	60	51.60	83.2	29.93
1	5	0.5	20	75.66	89.28	83.98
2	5	0.5	40	84.24	89.88	84.90
3	5	0.5	60	87.08	89.28	87.56
4	5	1.5	20	73.30	88.04	80.32
5	5	1.5	40	66.23	88.12	72.61
6	5	1.5	60	66.60	87.88	72.01
7	5	2.5	20	46.60	86.84	67.41
8	5	2.5	40	57.64	86.68	68.50
9	5	2.5	60	65.00	86.48	69.36
1	7	0.5	20	85.94	90.8	86.71
2	7	0.5	40	83.58	90.96	86.67
3	7	0.5	60	81.89	91.2	86.78

4	7	1.5	20	59.43	90.2	74.62
5	7	1.5	40	62.55	90.56	72.19
6	7	1.5	60	64.90	90.36	74.56
7	7	2.5	20	56.79	89.6	68.68
8	7	2.5	40	48.49	89.12	56.18
9	7	2.5	60	55.47	89.28	69.87
1	9	0.5	20	86.69	85.4	87.24
2	9	0.5	40	82.26	85.6	87.96
3	9	0.5	60	84.34	85.68	88.29
4	9	1.5	20	57.45	85.32	72.39
5	9	1.5	40	56.32	84.8	74.47
6	9	1.5	60	58.58	84.92	72.91
7	9	2.5	20	42.17	84.28	62.70
8	9	2.5	40	40.66	83.76	62.52
9	9	2.5	60	49.62	83.96	51.11
1	11	0.5	20	90.28	77.32	75.52
2	11	0.5	40	87.83	76.8	70.12
3	11	0.5	60	86.32	75.24	68.50
4	11	1.5	20	59.06	78.32	19.25
5	11	1.5	40	62.26	77.44	24.86
6	11	1.5	60	58.20	78.44	17.62
7	11	2.5	20	11.79	77.28	7.66
8	11	2.5	40	15.47	78.28	9.47
9	11	2.5	60	19.15	78.56	13.09

4.2. Removal Efficiency of Alum for Wastewater Treatment

Aluminum sulfate was most widely used coagulant for wastewater purification but it was needed huge foreign currency to buy the coagulant materials so it needs to solve the problem by locally available material and our community that are suffered by shortage of pure water must raise to see their environment to solve the problems. The pH of wastewater greatly influenced the reduction in turbidity. At greater pH values, the lowest removal efficiency was obtained. The variation in the rate of stirring did not affect the efficiency of coagulation.

Aluminum sulfate is a chemical compound with the formula $Al_2(SO4)_3$. It is soluble in water and is mainly used as a flocculating agent in the purification of drinking water and waste water treatment plants, and also in paper manufacturing. Aluminum is regarded as an important poisoning factor in dialysis encephalopathy. Aluminum is one of the factors which might contribute to Alzimer disease. Aluminum reaction with water reduces water pH and its efficiency in cold water(Jatav et al., 2016).

Aluminum sulfate is an aluminum salt, which can be used for wastewater treatment as a coagulant. In this thesis Alum conducted experiment is only for evaluation to the Okra seed.

Table 3 percentage removal of Alum at different dose, time and pH.

Run	pH	Dosage (g)	Time (min)	Color Removal (%)	%ge Removal of TDS	%ge Removal Turbidity
1	3	0.5	20	99.05	66.60	92.49
2	3	0.5	40	99.24	67.20	92.65
3	3	0.5	60	99.34	63.08	94.80
4	3	1.5	20	99.8	50.08	92.32
5	3	1.5	40	99.7	50.16	93.12
6	3	1.5	60	99.53	48.44	93.01
7	3	2.5	20	99.43	40.72	92.94
8	3	2.5	40	99.7	36.48	96.16
9	3	2.5	60	99.53	35.12	93.37
1	5	0.5	20	99.245	77.12	92.14
2	5	0.5	40	99.339	76.44	92.65
3	5	0.5	60	99.15	78.08	92.49
4	5	1.5	20	98.49	62.04	90.89
5	5	1.5	40	98.49	61.64	92.63
6	5	1.5	60	98.38	61.60	91.20
7	5	2.5	20	97.83	46.84	88.83
8	5	2.5	40	94.06	46.72	88.05
3	7	0.5	60	94.34	78.44	89.06
4	7	1.5	20	97.83	66.04	90.73
5	7	1.5	40	97.45	66.60	91.22
6	7	1.5	60	97.83	66.32	91.24
7	7	2.5	20	98.2	50.48	89.64
8	7	2.5	40	97.73	50.36	90.30
9	7	2.5	60	97.45	50.16	89.93
1	9	0.5	20	96.41	77.12	90.22
2	9	0.5	40	96.6	76.96	91.78
3	9	0.5	60	97.07	77.20	88.52
4	9	1.5	20	96.79	61.20	91.36
5	9	1.5	40	85.75	61.16	88.14
6	9	1.5	60	96.41	61.60	81.97
7	9	2.5	20	97.64	44.96	90.13
8	9	2.5	40	97.83	44.72	91.56

9	9	2.5	60	97.07	45.00	89.08
1	11	0.5	20	97.73	72.20	90.01
2	11	0.5	40	97.83	72.08	89.39
3	11	0.5	60	95.75	71.92	88.85
4	11	1.5	20	81.13	56.84	90.84
5	11	1.5	40	94.52	58.32	91.58
6	11	1.5	60	92.83	57.20	87.40
7	11	2.5	20	63.96	43.76	87.38
8	11	2.5	40	75.57	44.48	90.68
9	11	2.5	60	23.2	43.40	86.84

4.3 Effect of Operating parameters on the turbid water

4.3.1 Effects of pH on Okra

The effects of pH were investigated using a medium containing the original sample of turbid water (55.23 NTU) and a pH range of 3, 5, 7, 9& 11 with a volume of 100 ml of coagulant extract. Based on this data, it was observed that both Okra and Alum coagulants provides a significant reduction in turbidity (optimum turbidity removal) at 3&5 pH, and it was decline but not effective at 7, 9& 11 pH.

Figure-6 indicates that the interaction pH with percentage removal efficiency of Okra on TDS, Color Removal & Turbidity.

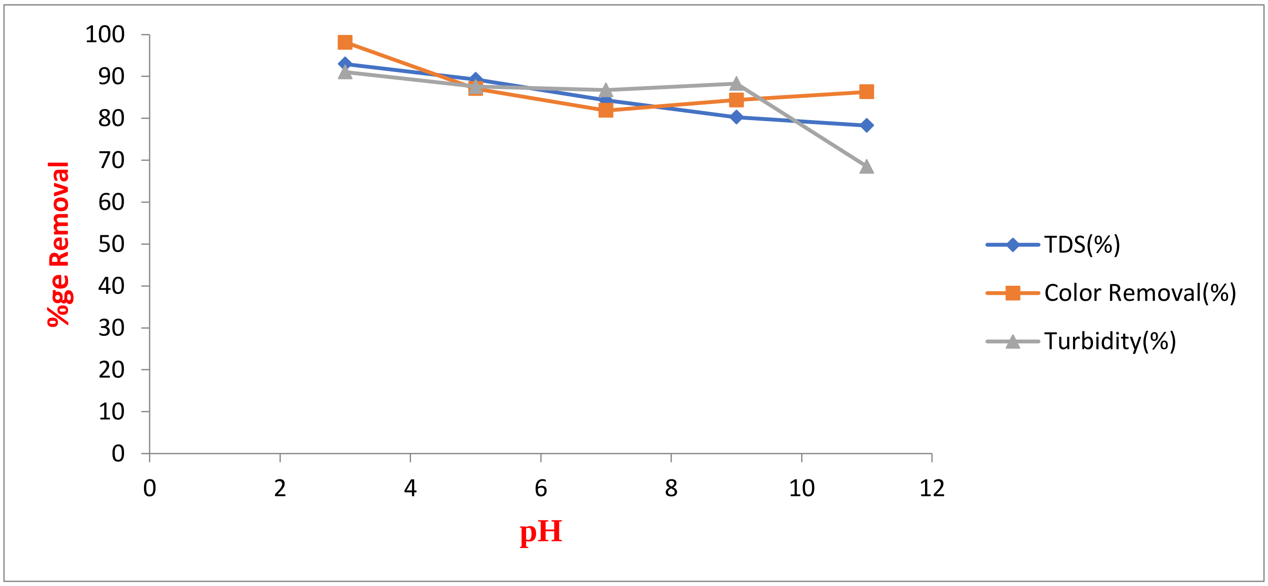

Figure 6. The effect of pH on the optimum wastewater treatment outcomes using Okra.

The use of natural substances for coagulation in place of chemicals is a promising alternative for the treatment of wastewater. Natural coagulants are safe for consumption (owing to their plant-origins) and are biodegradable in the environment (Nath et al., 2020).

The coagulation process has been described as an efficient method for wastewater treatment with variations in temperature, dosage, and concentration. (Qu et al., 2018).

4.3.2 Effects of Dosage on Okra

The (figure 7) below indicates that when dosage that are used in treatment decreases the wastewater treatment capacity was increased. The sludge of okra is ecologically friend it doesn't affect the environment.

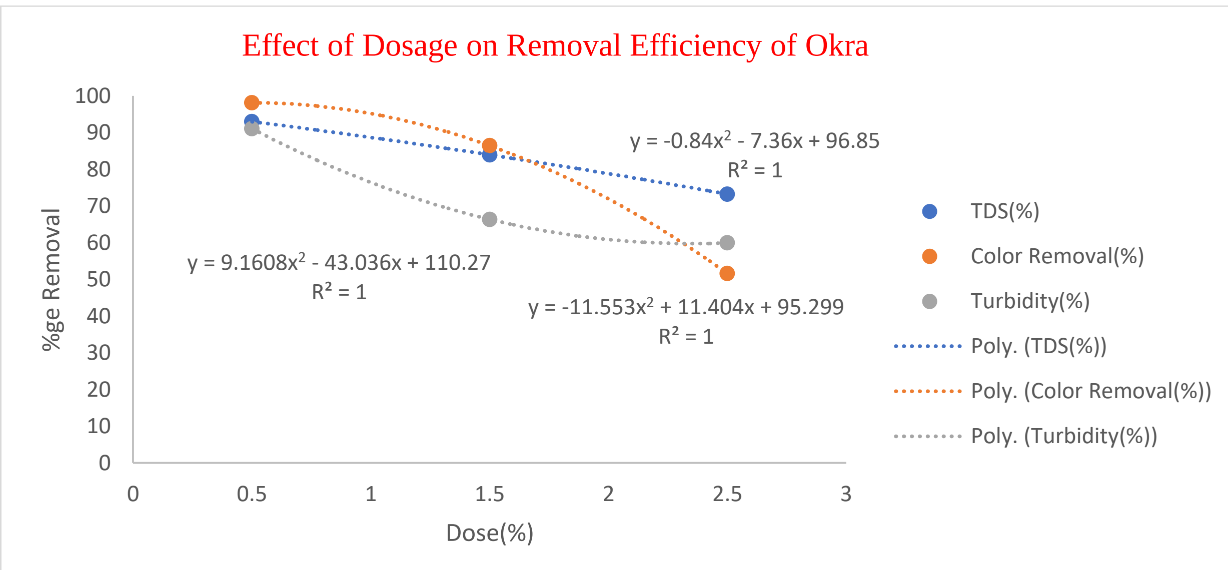

Figure 7the effect of Dosage on the removal efficiency of Okra & Alum.

4.1.2 Effects of pH on TDS using Okra & Alum

Fig-8 indicates that the treatment coagulant of both Okra and Alum at pH 3,9&11 increases TDS value but at the pH of 5&7 decreases the value of TDS.

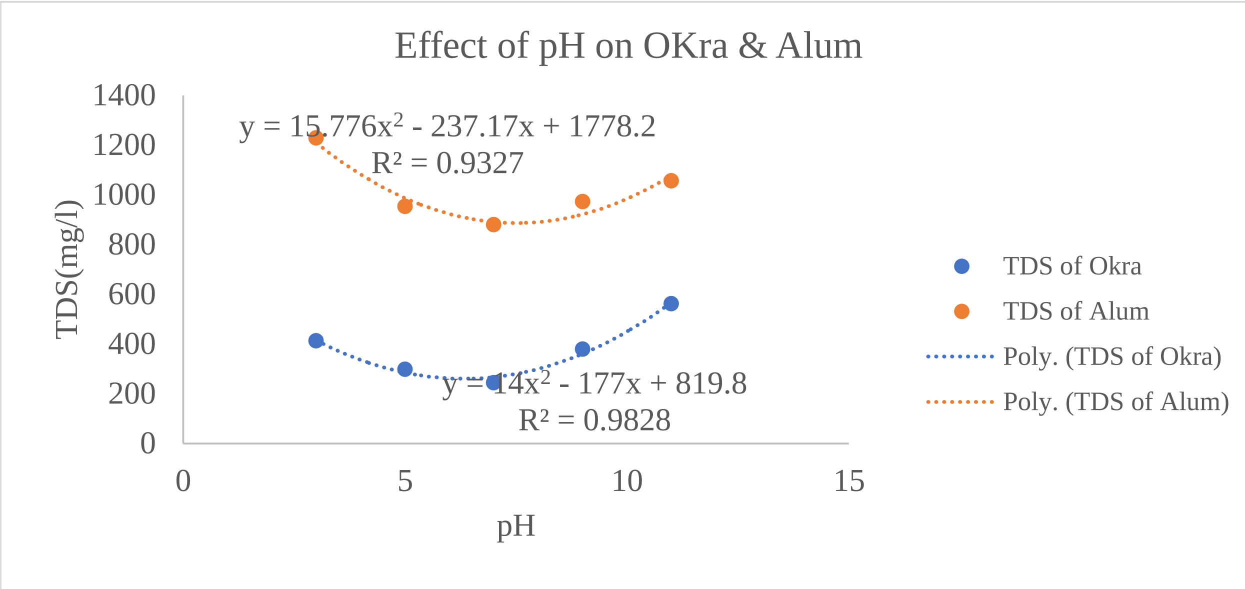

Figure 8 the effect of pH on TDS by using Okra & Alum.

Fig-9 indicates that the effect of time on the average settling time of the treatment of wastewater sample on the TDS value was increased.

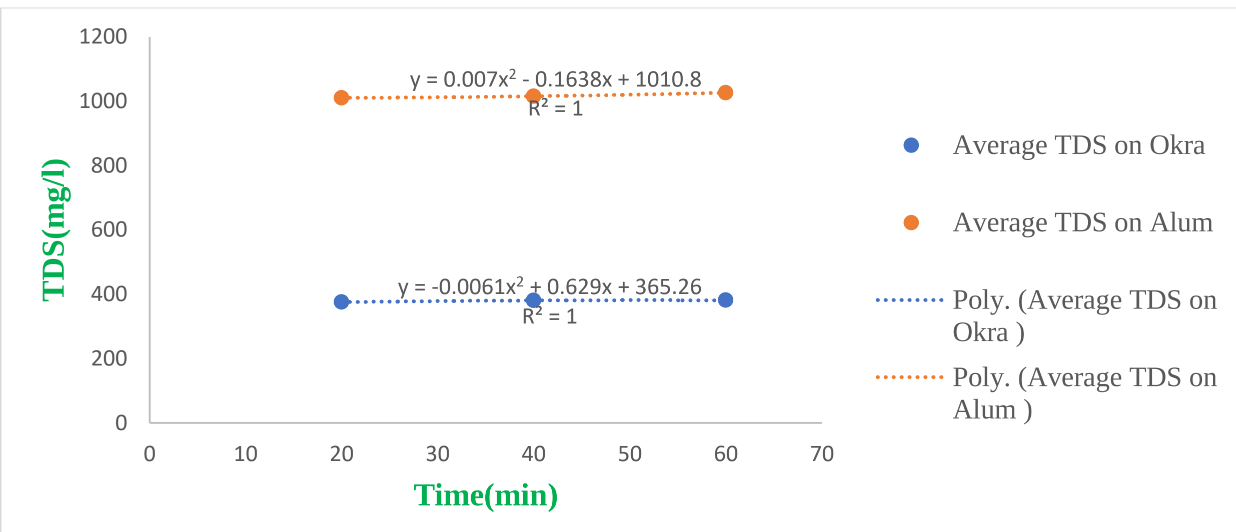

Figure 9 the effect of Time on TDS by using Okra and Alum.

4.4 Turbidity in Drinking Water

Turbidity can be easily, accurately and rapidly measured, and is commonly used for operational monitoring of control measures included in water safety plans (WSPs), the recommended approach to managing drinking-water quality in the WHO Guidelines for Drinking-water Quality (WHO, 2017). It can be used as a basis for choosing between alternative source waters and for assessing the performance of a number of control measures, including coagulation and clarification, filtration, disinfection and management of distribution systems.

Interaction of Time and pH

This 3D figure shows the Turbidity removal efficiency was maximum when the pH value reaches at 3 and Time at 60min.

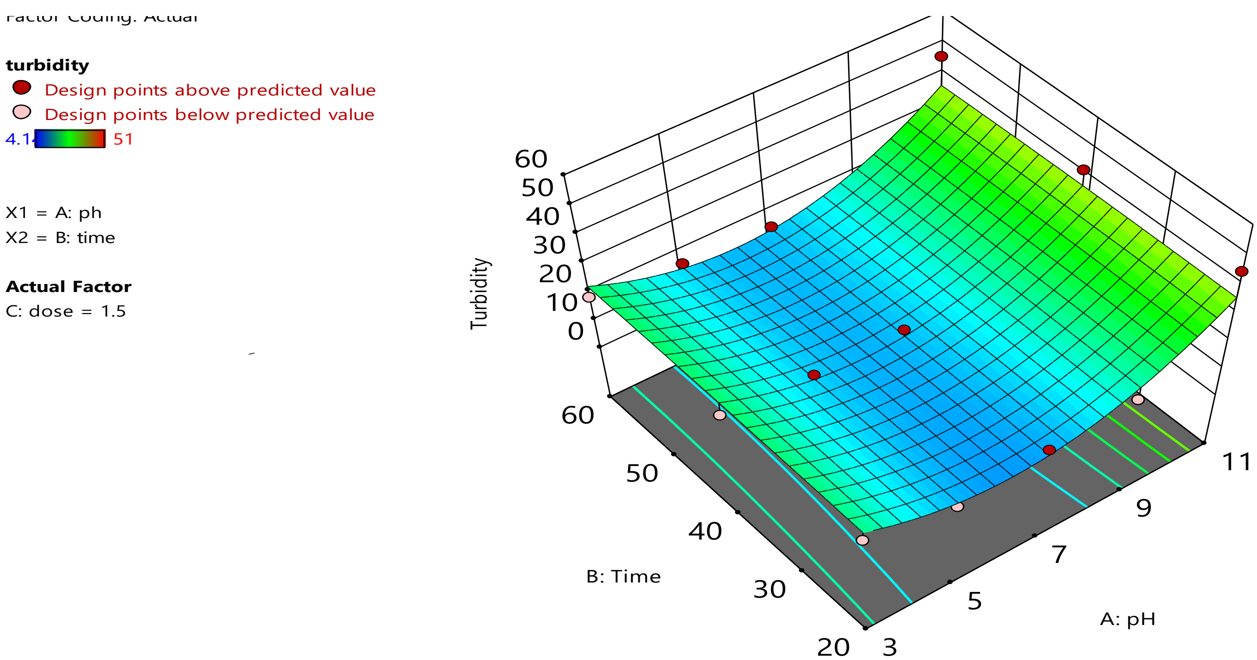

Figure 10 experimental result of Turbidity removals quadratic model of Okra.

Turbidity can be used as an operational parameter to assess the likely effectiveness of disinfection, and as a basis for setting disinfectant doses and modifying contact times (where such modification is possible).

Turbidity above 1–2 NTU reduces the efficacy of chlorination by increasing chlorine demand and potentially shielding microorganisms from inactivation (WHO, 2017).

The figure below indicates that the effect of pH on the average Turbidity removal using Okra and Alum was different with respect to pH. Oka seed at the pH 11 the average turbidity removal is decreased but at the pH 3,5, 7&9 the average turbidity removal of okra is increased. The effect of pH on average turbidity removal using Alum at the pH 3,5,7&9 is more effective than 11.

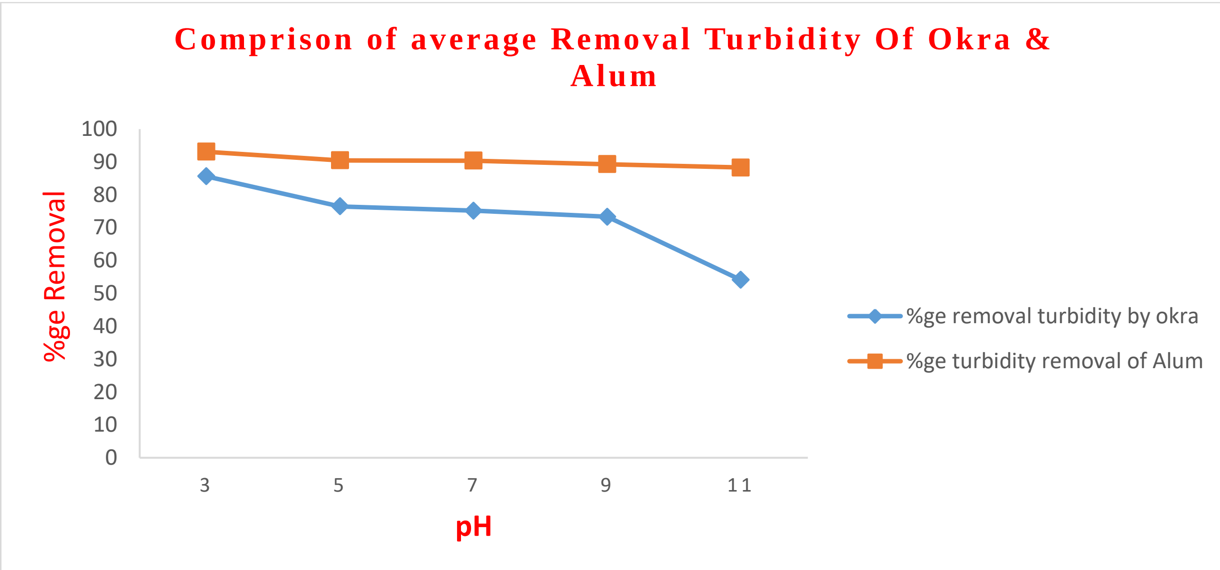

Figure 11 the effect of pH on Turbidity Removal using Okra and Alum.

Turbidity should ideally be kept below 1 NTU because of the recorded impacts on disinfection. This is achievable in large well-run municipal supplies, which should be able to achieve less than 0.5 NTU before disinfection at all times and an average of 0.2 NTU or less, irrespective of source water type and quality. However, keeping turbidity below 1 NTU is not always possible in low-resource settings including small supplies; in such cases, the aim should be to keep turbidities below 5 NTU. At turbidities above 1 NTU, higher disinfection doses or contact times will be required to ensure that adequate Ct or UV light intensity is achieved.

4.4.1 Determination of optimum dosage of coagulant for turbidity removal

Turbidity is the measure of the degree to which the water loses its transparency due to the presence of suspended particulates. Turbidity measurement could also be used to provide an estimation of the TSS (Total Suspended Solids) concentration.

It is essential to eliminate the turbidity of water in order to effectively disinfect it for drinking purposes. Jar test experiments were performed by varying the coagulant dosage (compared in Table18& Table19, for *Alum* and Okra) to find the optimum dosage for maximum turbidity removal at their optimum pH. From figure 6&7, it was observed that turbidity of water sample decreases with decrease of coagulant dosage& decrease of pH value, both coagulants gave good results(WHO, 2017).

Turbidity refers to water clarity and is used to indicate water quality and filtration effectiveness. It is related to the scattering of light by fine and suspended particles that cause water to have a cloudy appearance. Turbidity is mainly caused by suspended matter or impurities and the major source in the open water zone of most rivers are typically clays and silts from soil erosion, re-suspended bottom sediments, building and road construction, urban runoff, decaying plants, industrial wastes, and organic detritus from stream and/or water discharges. Elevated concentrations of solids affect the clarity of the water (Tefera, 2017).

Table 4 Comparison of turbidity removal efficiency of Alum and okra on medium turbid water sample

pH	turbidity removal of Okra (NTU)	coagulant dose (g)	turbidity removal of Alum (NTU)	coagulant dose(g)	volume of sample(mg/l)
3	6.24	0.5	4.15	0.5	100
3	4.14	0.5	4.06	0.5	100
3	4.95	0.5	2.87	0.5	100
3	17.6	1.5	4.24	1.5	100
3	17.4	1.5	3.8	1.5	100
3	18.6	1.5	3.86	1.5	100
3	29.3	2.5	3.9	2.5	100
3	38.2	2.5	3.75	2.5	100
3	38.7	2.5	3.66	2.5	100

Optimum dosage of *Alum* for maximum turbidity removal was found to be 1.5g with a removal efficiency 99.8% and for Okra seed extract optimum dose was found to be 0.5 with a removal efficiency of 98.113 %.

Figure 13, shows the turbidity removal in synthetic water by coagulation active agent in various sections of Okra's plant that extracted with distilled water. The initial turbidity of synthetic water was set at 55.23 NTU. For Okra's seed, the turbidity was significantly decreased down to a 4.14NTU at dosage of 100 mg/L, whereas further addition of coagulant leads to an increase in residual turbidity. Therefore, the optimum removal efficiency for turbidity with Okra's seed was 92.5 % and Alum was 94.8% which was attained at the dosage of 100 mg/L.

Moreover, the result shows that Okra's seed has the potential advantage as natural coagulant for turbidity removal. However, the seed is conventionally consumed by human being as protein riches vegetable and may be economically feasible to be used as coagulant. The dried Okra seed could be proposed as an alternative coagulant in water treatment process, due to its similarity in coagulation behavior.

4.4.2 Total Dissolved Solid (TDS)

The presence of dissolved solids in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/liter; good, between 300 and 600 mg/liter; fair, between 600 and 900 mg/liter; poor, between 900 and 1200 mg/liter; and unacceptable, greater than 1200 mg/liter. Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste(Devesa & Dietrich., 2018).

4.4.3 Expected Levels of TDS

TDS values in lakes and streams are typically found to be in the range of 50 to 250 mg/L. In areas of especially hard water or high salinity, TDS values may be as high as 500 mg/L. Drinking water will tend to be 25 to 500 mg/L TDS.

United States Drinking Water Standards include a recommendation that TDS in drinking water should not exceed 500 mg/L TDS. Fresh distilled water, by comparison, will usually have a conductivity of 0.5 to 1.5 mg/L TDS(Devesa & Dietrich., 2018).

Table 5 Comparison of experimental results of TDS on Okra & Alum at pH 3.

		Okra	Alum
pH	Dosage (g)	TDS(Mg/l)	TDS (mg/l)
3	0.5	453	835
3	0.5	445	820
3	0.5	426	923
3	1.5	417	1248
3	1.5	396	1246
3	1.5	402	1289
3	2.5	328	1480
3	2.5	419	1588
3	2.5	420	1622

Since the beginning of time, water has been both praised and blamed for good health and human ills. We now know the real functions of water in the human body are to serve as a solvent and medium for the transport of nutrients and wastes to and from cells throughout the body, a regulator of temperature, a lubricator of joints and other tissues, and a participant in our body's biochemical reactions(Drinking & Standards, 2003). Total dissolved solid (TDS) is a measure of the combined content of all inorganic and organic matter which is found in solution in water. Water low in TDS is defined in this paper as that containing between 1-100 milligrams per liter (mg/l) of TDS. This is typical of the water quality obtained from distillation, reverse osmosis, and deionization point-of-use water treatment of public or private water supplies that are generally available to consumers in the world. Worldwide, there are no agencies having scientific data to support that drinking water with low TDS will have adverse health effects. There is a recommendation regarding high TDS, which is to drink water with less than 500mg/L. Some people speculate that drinking highly purified water, treated by distillation, reverse osmosis, or deionization, "leaches" minerals from the body and thus causes mineral deficiencies with subsequent ill health effects.

4.4.4 Rationale on TDS

1. The most important aspect of TDS with respect to drinking water quality is, its effect on taste. The palatability of drinking water with a TDS level less than 600 mg/L is generally considered to be good. Drinking water supplies with TDS levels greater than 1200 mg/L are unpalatable to most consumers.
2. Concentrations of TDS above 500 mg/L result in excessive scaling in water pipes, water heaters, boilers and household appliances.
3. An aesthetic objective of ≤500 mg/L should ensure palatability and prevent excessive scaling. However, it should be noted that at low levels TDS contributes to the palatability of drinking water(Islam et al., 2017).

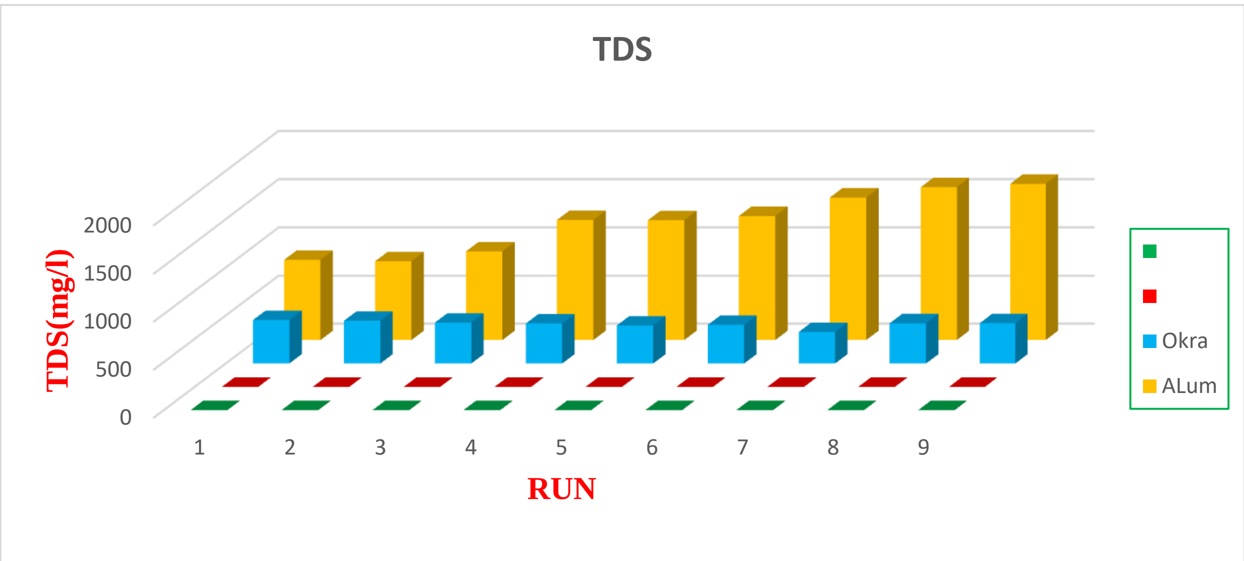

Figure 12Comparison of experimental results of TDS on Okra & Alum at pH 3.

4.4.5 Color Removal

Drinking water supplied by local utilities directly impacted by color as consumers demand an aesthetically pleasing clear supply at all times. Water treatment methods which effectively remove color from water and wastewater can not only help to avoid fines, but can also save money by allowing wastewater to be reused during manufacturing processes.

The result of average color removal efficiencies at different pH of Okra and Alum. Figure-14 below shows that the results of color removal at minimum pH is higher than the maximum.

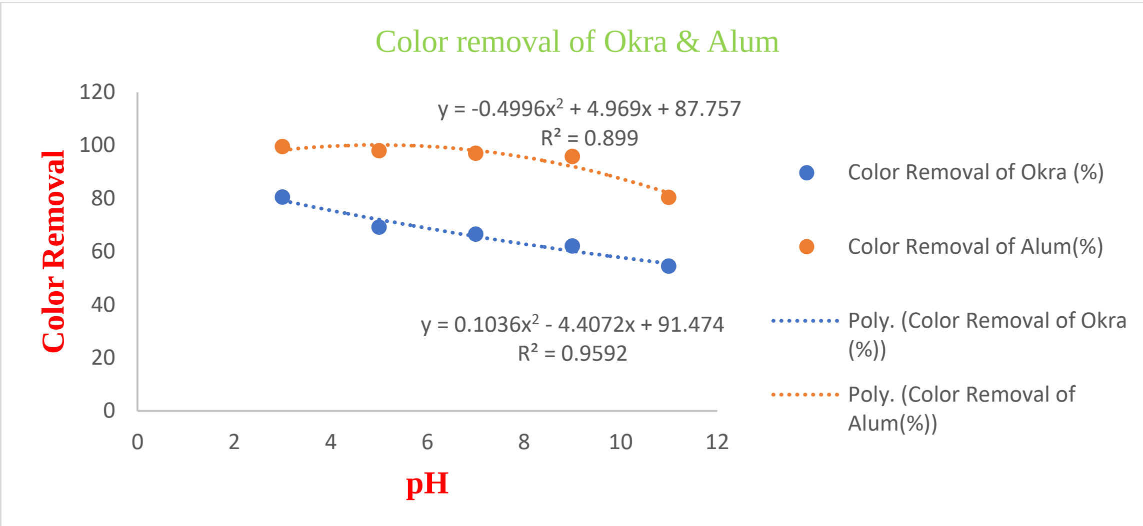

Figure 13 the effect of pH on the color removal of Okra & Alum.

Table 6 effects of color removals efficiencies on Okra seed & Alum at different coagulant doses.

pH	Dosage (g)	Okra	Alum
		Color Removal (%)	Color Removal (%)
3	0.5	89.056	99.05
3	0.5	95.75	99.24
3	0.5	98.113	99.34
3	1.5	77.36	99.8
3	1.5	88.019	99.7
3	1.5	86.41	99.53
3	2.5	73.019	99.43
3	2.5	65.09	99.7
3	2.5	51.6	99.53

The figure-15 below indicates that the color removal efficiency of Okra and Alum was comparing. The red color is color removal efficiency of Okra & the yellow color indicates color removal efficiency of Alum. The optimum color removal of Okra at pH3& dosage of 0.5g is 98.113%.

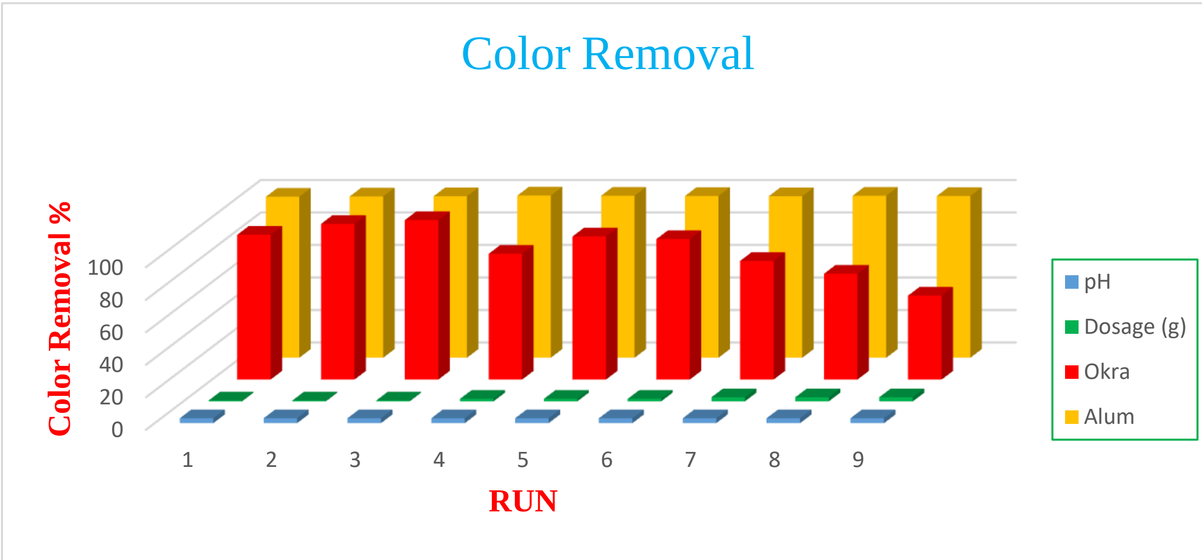

Figure 14 Comparison of color removals on Okra seed & Alum at pH3.

4.4.6 Calculation of Color Removal

For the unknown color, wavelength was ascertained by getting the maximum absorption at particular concentrations of the color in the UV-Vis spectrophotometer. Then six different concentrations of the dye ranging from 0.1-0.5ml were made and standard curves (by plotting graph between concentration and absorption of the dye/color) were developed for individual dyes/color with known wavelength by measuring the absorption in spectrophotometer at particular concentration and calibration values are developed. As mentioned above, concentrations of the dye/color in supernatant solution collected at various interval of time before and after treatment were calculated using standard curves at particular wavelength corresponding to the dye/color taken into consideration during the experimentation or simply by multiplying the absorption with the calibration values developed for particular dye. The color removal is calculated by taking the difference between the calculated concentrations of the dye/color before and after treatment.

4.5 ANOVA by Quadratic model for Okra & Alum

ANOVA by Quadratic model for Okra

I. ANOVA for Color Removal

Table 7 ANOVA for the % removal of ***color by quadratic model using Okra***

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	16642.13	6	2773.69	52.54	< 0.0001	significant
A-ph	3137.21	1	3137.21	59.43	< 0.0001	
B-time	27.40	1	27.40	0.5191	0.0456	
C-dose	12058.67	1	12058.67	228.42	< 0.0001	
AB	0.4474	1	0.4474	0.0085	0.9271	
AC	1418.39	1	1418.39	26.87	< 0.0001	
BC	0.0064	1	0.0064	0.0001	0.9912	
Residual	2006.11	38	52.79			
Cor Total	18648.24	44				

The **Model F-value** of 52.54 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. **P-values** less than 0.0500 indicate model terms are significant. In this case A, C, AC are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table 8 ***Fit Statistics for color using okra***

Std. Dev.	7.27	**R^2**	0.8924
Mean	66.52	**Adjusted R^2**	0.8754
C.V. %	10.92	**Predicted R^2**	0.8262
		Adeq Precision	22.9004

The **Predicted R^2** of 0.8262 is in reasonable agreement with the **Adjusted R^2** of 0.8754; i.e., the difference is less than 0.2. **Adeq Precision** measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 22.900 indicates an adequate signal. This model can be used to navigate the design space.

II. ANOVA for Quadratic model Turbidity

Table 9 ANOVA for the removal of ***turbidity by quadratic model using Okra***

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	6392.45	9	710.27	18.81	< 0.0001	significant
A-ph	1142.90	1	1142.90	30.27	< 0.0001	
B-time	9.95	1	9.95	0.2636	0.0109	
C-dose	3100.43	1	3100.43	82.11	< 0.0001	
AB	1.89	1	1.89	0.0502	0.3241	
AC	28.41	1	28.41	0.7525	0.3916	
BC	6.13	1	6.13	0.1623	0.3895	
A^2	2052.48	1	2052.48	54.36	< 0.0001	
B^2	2.06	1	2.06	0.0544	0.8169	
C^2	48.19	1	48.19	1.28	0.2663	
Residual	1321.54	35	37.76			
Cor Total	7713.99	44				

The **Model F-value** of 18.81 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. **P-values** less than 0.0500 indicate model terms are significant. In this case A, C, A^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table 10 Fit Statistics for Turbidity using Okra

Std. Dev.	6.14	**R^2**	0.8987
Mean	19.50	**Adjusted R^2**	0.7846
C.V. %	31.52	**Predicted R^2**	0.6920
		Adeq Precision	15.8030

The **Predicted R^2** of 0.6920 is in reasonable agreement with the **Adjusted R^2** of 0.7846; i.e., the difference is less than 0.2. **Adeq Precision** measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 15.803 indicates an adequate signal. This model can be used to navigate the design space.

III. ANOVA for Quadratic model

*Table 11 ANOVA for TDS **by quadratic model using Okra***

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	5.256E+05	9	58395.69	56.51	< 0.0001	significant
A-ph	1.302E+05	1	1.302E+05	125.97	< 0.0001	
B-time	240.83	1	240.83	0.2330	0.0323	
C-dose	1032.53	1	1032.53	0.9991	0.0244	
AB	77.07	1	77.07	0.0746	0.4864	
AC	5.40	1	5.40	0.0052	0.5428	
BC	296.45	1	296.45	0.2869	0.5956	
A^2	3.930E+05	1	3.930E+05	380.29	< 0.0001	
B^2	59.21	1	59.21	0.0573	0.8122	
C^2	650.71	1	650.71	0.6296	0.4328	
Residual	36170.74	35	1033.45			
Cor Total	5.617E+05	44				

The **Model F-value** of 56.51 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. **P-values** less than 0.0500 indicate model terms are significant. In this case A, A^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table 12 Fit Statistics for TDS using Okra

Std. Dev.	32.15	**R^2**	0.9356
Mean	379.04	**Adjusted R^2**	0.9191
C.V. %	8.48	**Predicted R^2**	0.8751
		Adeq Precision	21.1191

The **Predicted R^2** of 0.8751 is in reasonable agreement with the **Adjusted R^2** of 0.9191; i.e., the difference is less than 0.2. **Adeq Precision** measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 21.119 indicates an adequate signal. This model can be used to navigate the design space.

ANOVA by Quadratic model for Alum

Table 13 ANOVA for the ***Color Removal (%) by quadratic model using Alum***

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	3227.54	6	537.92	5.26	0.0005	significant
A-pH	1477.72	1	1477.72	14.44	0.0005	
B-Dose (g)	546.34	1	546.34	5.34	0.0264	
C-Time (min)	41.90	1	41.90	0.4094	0.0261	
AB	1013.33	1	1013.33	9.90	0.0032	
AC	60.49	1	60.49	0.5910	0.4468	
BC	87.76	1	87.76	0.8574	0.3603	
Residual	3889.58	38	102.36			
Cor Total	7117.11	44				

The **Model F-value** of 5.26 implies the model is significant. There is only a 0.05% chance that an F-value this large could occur due to noise. **P-values** less than 0.0500 indicate model terms are significant. In this case A, B, AB are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table 14 Fit Statistics for Color using Alum

Std. Dev.	10.12	**R^2**	0.9535
Mean	94.06	**Adjusted R^2**	0.8672
C.V. %	10.76	**Predicted R^2**	0.7998
		Adeq Precision	9.8238

The **Predicted R^2** of 0.7998 is as close to the **Adjusted R^2** of 0.7672 as one might normally expect; i.e. the difference is not more than 0.2. A ratio greater than 4 is desirable. Your ratio of 9.824 indicates an adequate signal. This model can be used to navigate the design space.

*Table 15 ANOVA for the **Turbidity Removal (NTU) by quadratic model using Alum***

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	29.04	3	9.68	8.38	0.0002	significant
A-pH	22.31	1	22.31	19.31	< 0.0001	
B-Dose (g)	3.72	1	3.72	3.22	0.0400	
C-Time (min)	3.00	1	3.00	2.60	0.1147	
Residual	47.38	41	1.16			
Cor Total	76.41	44				

The **Model F-value** of 8.38 implies the model is significant. There is only a 0.02% chance that an F-value this large could occur due to noise. **P-values** less than 0.0500 indicate model terms are significant. In this case A is a significant model term.

Table 16 Fit Statistics for Turbidity using Alum

Std. Dev.	1.07	**R^2**	0.9800
Mean	5.27	**Adjusted R^2**	0.8346
C.V. %	20.41	**Predicted R^2**	0.8603
		Adeq Precision	10.3868

The **Predicted R^2** of 0.2603 is in reasonable agreement with the **Adjusted R^2** of 0.3346; i.e., the difference is less than 0.2. **Adeq Precision** measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 10.387 indicates an adequate signal. This model can be used to navigate the design space.

*Table 17 ANOVA for the **TDS (mg/l) by quadratic model using Alum***

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	4.629E+06	9	5.143E+05	216.97	< 0.0001	significant
A-pH	95452.90	1	95452.90	40.27	< 0.0001	
B-Dose (g)	4.025E+06	1	4.025E+06	1697.88	< 0.0001	
C-Time (min)	1904.03	1	1904.03	0.8033	0.3762	
AB	308.27	1	308.27	0.1301	0.4205	
AC	4717.07	1	4717.07	1.99	0.1672	
BC	594.05	1	594.05	0.2506	0.4198	
A^2	5.010E+05	1	5.010E+05	211.35	< 0.0001	
B^2	7.51	1	7.51	0.0032	0.9554	
C^2	80.28	1	80.28	0.0339	0.8551	
Residual	82961.68	35	2370.33			
Cor Total	4.712E+06	44				

The **Model F-value** of 216.97 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. **P-values** less than 0.0500 indicate model terms are significant. In this case A, B, A^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table 18 Fit Statistics for TDS using Alum

Std. Dev.	48.69	**R^2**	0.9824
Mean	1017.36	**Adjusted R^2**	0.9779
C.V. %	4.79	**Predicted R^2**	0.9706
		Adeq Precision	47.0283

The **Predicted R^2** of 0.9706 is in reasonable agreement with the **Adjusted R^2** of 0.9779; i.e., the difference is less than 0.2. **Adeq Precision** measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 47.028 indicates an adequate signal. This model can be used to navigate the design space.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Surface water can be treated and used for Domestic purposes. There is a great scope of doing so this can be achieved by using a Natural Coagulant namely OKRA SEEDS or coagulant pH adjustment by addition of neutralizing substances can work very well in meeting the discharge standards after treatment and reuse standards after the treatment.

The increase in water demand for domestic uses, caused by population growth and by the rising standard of living, together with progressive environmental pollution problems have led to over utilization of renewable drinking water sources and the diminution of water quality. As we all know that our country is a developing country which lacks behind in both in technology as well as finance, thus treatment of water by such a natural coagulant is both economically safe and sustainable.

A comparative study was made Okra seeds, and Alum for different dosages and effect on Time, Turbidity, TDS, Color, Dosage& pH was calculated. On comparison both alum and okra gave almost similar results moreover Alum, in few cases gave even better results. While the sludge obtained by treatment alum was higher than that of okra seeds. It can be thus suggested that we can use locally available material okra seeds to treat low turbid wastewater which is environmentally friend as well as cost effective and naturally available. A continuous monitoring is required to check the pH for a proper removal as compared to the traditional coagulants, so that they can easily be replaced by the natural ones.

It was thus obtained that the maximum removal efficiency of alum and okra seeds were 99.8% and 98.113% for 100mg/l sample of water respectively. In short natural coagulants are sustainable and economical way of water treatment process. The use of natural materials of a plant for wastewater treatment has been adopted. However, lack of enough knowledge on the exact nature and mechanism on how these impurities in water make them less likely to compete with conventional treatment. Using such natural ingredient is important because natural compound that has significant application and plays role in water treatment processes and it is degradable.

5.2. RECOMMENDATIONS

This study helped in the development of some recommendations that will be extremely useful in resolving the major issues identified during the study. The following are the most important ones:

- Create awareness among the community and government organizations about the Okra seed, which is locally available in Gambella, for wastewater treatment coagulation.
- The concerned body must follow and enforced to start the next phase that are growing Okra to use to the treatment efficiency and minimizing the foreign currency.
- Water demand for household purposes has increased as a result of population growth and rising living standards, as well as progressive environmental degradation issues, resulting in overuse of renewable drinking water sources and deterioration of water quality.
- Aluminum sulfate is very expensive, and people's ability to pay for services is limited. Skills and technology are also scarce. As a result, locally available materials can be used to achieve a long-term safe water supply.
- As a result, it is advised that we use locally accessible okra seeds to treat low turbid wastewater, which is both ecologically friendly and economically effective, as well as naturally available.

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APPENDIXS

Table 19. Okra wastewater treatment results

Run	pH	Dosage (g)	Time(min)	Absorbance before	Absorbance after	Color Removal after (%)	TDS before treatment (mg/l)	TDS after treatment (mg/l)	%ge Removal of TDS	Initial Turbidity (NTU)	Turbidity after treat (NTU)	%ge Removal of Turbidity (NTU)
1	3	0.5	20	1.06	0.116	89.056	2500	453	81.88	55.23	6.24	88.702
2	3	0.5	40	1.06	0.045	95.75	2500	445	82.2	55.23	4.14	92.504
3	3	0.5	60	1.06	0.02	98.113	2500	426	82.96	55.23	4.95	91.037
4	3	1.5	20	1.06	0.24	77.36	2500	417	83.32	55.23	17.6	68.133
5	3	1.5	40	1.06	0.127	88.019	2500	396	84.16	55.23	17.4	68.495
6	3	1.5	60	1.06	0.144	86.41	2500	402	83.92	55.23	18.6	66.323
7	3	2.5	20	1.06	0.286	73.019	2500	328	86.88	55.23	29.3	46.949
8	3	2.5	40	1.06	0.37	65.09	2500	419	83.24	55.23	38.2	30.835
9	3	2.5	60	1.06	0.513	51.6	2500	420	83.2	55.23	38.7	29.929
1	5	0.5	20	1.06	0.258	75.66	2500	268	89.28	55.23	8.85	83.976
2	5	0.5	40	1.06	0.167	84.24	2500	253	89.88	55.23	8.34	84.900
3	5	0.5	60	1.06	0.137	87.075	2500	268	89.28	55.23	6.87	87.561
4	5	1.5	20	1.06	0.283	73.3	2500	299	88.04	55.23	10.87	80.319
5	5	1.5	40	1.06	0.358	66.226	2500	297	88.12	55.23	15.13	72.605
6	5	1.5	60	1.06	0.354	66.6	2500	303	87.88	55.23	15.46	72.008
7	5	2.5	20	1.06	0.566	46.6	2500	329	86.84	55.23	18	67.409
8	5	2.5	40	1.06	0.449	57.64	2500	333	86.68	55.23	17.4	68.495
9	5	2.5	60	1.06	0.371	65	2500	338	86.48	55.23	16.92	69.364
1	7	0.5	20	1.06	0.149	85.94	2500	230	90.8	55.23	7.34	86.710
2	7	0.5	40	1.06	0.174	83.58	2500	226	90.96	55.23	7.36	86.674
3	7	0.5	60	1.06	0.192	81.89	2500	220	91.2	55.23	7.3	86.783
4	7	1.5	20	1.06	0.43	59.43	2500	245	90.2	55.23	14.02	74.615

5	7	1.5	40	1.06	0.397	62.547	2500	236	90.56	55.23	15.36	72.189
6	7	1.5	60	1.06	0.372	64.9	2500	241	90.36	55.23	14.05	74.561
7	7	2.5	20	1.06	0.458	56.79	2500	260	89.6	55.23	17.3	68.676
8	7	2.5	40	1.06	0.546	48.49	2500	272	89.12	55.23	24.2	56.183
9	7	2.5	60	1.06	0.472	55.47	2500	268	89.28	55.23	16.64	69.871
1	9	0.5	20	1.06	0.141	86.69	2500	365	85.4	55.23	7.05	87.235
2	9	0.5	40	1.06	0.188	82.26	2500	360	85.6	55.23	6.65	87.959
3	9	0.5	60	1.06	0.166	84.34	2500	358	85.68	55.23	6.47	88.285
4	9	1.5	20	1.06	0.451	57.45	2500	367	85.32	55.23	15.25	72.388
5	9	1.5	40	1.06	0.463	56.32	2500	380	84.8	55.23	14.1	74.470
6	9	1.5	60	1.06	0.439	58.58	2500	377	84.92	55.23	14.96	72.913
7	9	2.5	20	1.06	0.613	42.17	2500	393	84.28	55.23	20.6	62.701
8	9	2.5	40	1.06	0.629	40.66	2500	406	83.76	55.23	20.7	62.520
9	9	2.5	60	1.06	0.534	49.62	2500	401	83.96	55.23	27	51.114
1	11	0.5	20	1.06	0.103	90.28	2500	567	77.32	55.23	13.52	75.521
2	11	0.5	40	1.06	0.129	87.83	2500	580	76.8	55.23	16.5	70.125
3	11	0.5	60	1.06	0.145	86.32	2500	619	75.24	55.23	17.4	68.495
4	11	1.5	20	1.06	0.434	59.06	2500	542	78.32	55.23	44.6	19.247
5	11	1.5	40	1.06	0.4	62.26	2500	564	77.44	55.23	41.5	24.860
6	11	1.5	60	1.06	0.443	58.2	2500	539	78.44	55.23	45.5	17.617
7	11	2.5	20	1.06	0.935	11.79	2500	568	77.28	55.23	51	7.659
8	11	2.5	40	1.06	0.896	15.47	2500	543	78.28	55.23	50	9.469
9	11	2.5	60	1.06	0.857	19.15	2500	536	78.56	55.23	48	13.091

Table 20. Alum wastewater treatment results

Run	pH	Dosage (g)	Time (min)	Absorbance before	Absorbance after	Color Removal (%)	TDS before treatment (mg/l)	TDS after treatment (mg/l)	%ge Removal of TDS (mg/l)	Initial Turbidity before (NTU)	Turbidity (NTU)	%ge Removal Turbidity (NTU)
1	3	0.5	20	1.06	0.01	99.05	2500	835	66.6	55.23	4.15	92.486
2	3	0.5	40	1.06	0.008	99.24	2500	820	67.2	55.23	4.06	92.649
3	3	0.5	60	1.06	0.007	99.34	2500	923	63.08	55.23	2.87	94.804
4	3	1.5	20	1.06	0.002	99.8	2500	1248	50.08	55.23	4.24	92.323
5	3	1.5	40	1.06	0.003	99.7	2500	1246	50.16	55.23	3.8	93.120
6	3	1.5	60	1.06	0.005	99.53	2500	1289	48.44	55.23	3.86	93.011
7	3	2.5	20	1.06	0.006	99.43	2500	1480	40.72	55.23	3.9	92.939
8	3	2.5	40	1.06	0.003	99.7	2500	1588	36.48	55.23	3.75	96.162
9	3	2.5	60	1.06	0.005	99.53	2500	1622	35.12	55.23	3.66	93.373
1	5	0.5	20	1.06	0.008	99.245	2500	572	77.12	55.23	4.34	92.142
2	5	0.5	40	1.06	0.007	99.339	2500	589	76.44	55.23	4.06	92.649
3	5	0.5	60	1.06	0.009	99.15	2500	549	78.08	55.23	4.15	92.486
4	5	1.5	20	1.06	0.016	98.49	2500	949	62.04	55.23	5.03	90.893
5	5	1.5	40	1.06	0.016	98.49	2500	959	61.64	55.23	4.07	92.631
6	5	1.5	60	1.06	0.017	98.38	2500	960	61.6	55.23	4.86	91.200
7	5	2.5	20	1.06	0.023	97.83	2500	1329	46.84	55.23	6.17	88.829
8	5	2.5	40	1.06	0.063	94.06	2500	1332	46.72	55.23	6.6	88.050
3	7	0.5	60	1.06	0.06	94.34	2500	539	78.44	55.23	6.04	89.064
4	7	1.5	20	1.06	0.023	97.83	2500	849	66.04	55.23	5.12	90.730
5	7	1.5	40	1.06	0.027	97.45	2500	835	66.6	55.23	4.85	91.219
6	7	1.5	60	1.06	0.023	97.83	2500	842	66.32	55.23	4.84	91.237
7	7	2.5	20	1.06	0.019	98.2	2500	1238	50.48	55.23	5.72	89.643
8	7	2.5	40	1.06	0.024	97.73	2500	1241	50.36	55.23	5.36	90.295
9	7	2.5	60	1.06	0.027	97.45	2500	1246	50.16	55.23	5.56	89.933
1	9	0.5	20	1.06	0.038	96.41	2500	572	77.12	55.23	5.4	90.223

2	9	0.5	40	1.06	0.036	96.6	2500	576	76.96	55.23	4.54	91.780
3	9	0.5	60	1.06	0.031	97.07	2500	570	77.2	55.23	6.34	88.521
4	9	1.5	20	1.06	0.034	96.79	2500	970	61.2	55.23	4.77	91.363
5	9	1.5	40	1.06	0.151	85.75	2500	971	61.16	55.23	6.55	88.141
6	9	1.5	60	1.06	0.038	96.41	2500	960	61.6	55.23	9.96	81.966
7	9	2.5	20	1.06	0.025	97.64	2500	1376	44.96	55.23	5.45	90.132
8	9	2.5	40	1.06	0.023	97.83	2500	1382	44.72	55.23	4.66	91.563
9	9	2.5	60	1.06	0.031	97.07	2500	1375	45	55.23	6.03	89.082
1	11	0.5	20	1.06	0.024	97.73	2500	695	72.2	55.23	5.52	90.005
2	11	0.5	40	1.06	0.023	97.83	2500	698	72.08	55.23	5.86	89.390
3	11	0.5	60	1.06	0.045	95.75	2500	702	71.92	55.23	6.16	88.847
4	11	1.5	20	1.06	0.2	81.13	2500	1079	56.84	55.23	5.06	90.838
5	11	1.5	40	1.06	0.058	94.52	2500	1042	58.32	55.23	4.65	91.581
6	11	1.5	60	1.06	0.076	92.83	2500	1070	57.2	55.23	6.96	87.398
7	11	2.5	20	1.06	0.382	63.96	2500	1406	43.76	55.23	6.97	87.380
8	11	2.5	40	1.06	0.259	75.57	2500	1388	44.48	55.23	5.15	90.675
9	11	2.5	60	1.06	0.814	23.2	2500	1415	43.4	55.23	7.27	86.837

Different Photos during Research Time

Annex 1 Photo during Research Time

A) at coagulation

B) at settling time

C) reading taken

D) vacuum pump


E) spectrophotometer

F) TDS reading


G) Color reading

H) TDS value writing

I) Lab material& samples

J) Lab material& samples