Textile wastewater treatment by using Cactus mucilage as A Biofloculant

Abdi Alkadir Seid

A Thesis Submitted to Department of Applied Chemistry

School of Applied Natural science

Presented in partial fulfilment of the Requirements of the degree of Master of Science in Chemistry (Industrial Chemistry)

Office of Graduate Studies

Adama Science and Technology University

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Adama, Ethiopia

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Advisor: Dr. Eshetu Bekele

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Declaration

I hereby declare that this Master's Thesis entitled "**Textile Wastewater treatment by using Cactus mucilage as A Bioflocculant**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other University. All sources of material that are used for this thesis have been duly acknowledged through citation.

Abdi Alkadir Seid __________________ ________________________

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I, the Advisor of this Thesis, hereby certify that I have read the revised Version of the Thesis entitled "**Textile Wastewater treatment by using Cactus as A Bioflocculant**" prepared under my guidance by **Abdi Alkadir Seid**, submitted in partial fulfilment of the degree of Masters of Science in Applied Chemistry. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedure.

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Approval page

I, the Advisor of the Thesis entitled "**Textile wastewater treatment by using Cactus mucilage as A Bioflocculant"** and developed by **Abdi Alkadir Seid,** hereby certify that the recommendation and suggestion made by the board of examiners are appropriately incorporated into the final version of the Thesis.

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We, the undersigned member of the Board of Reviewers of the Thesis by **Abdi Alkadir Seid** have read and evaluated the thesis entitled "**Textile wastewater treatment by using Cactus mucilage as A Bioflocculant"** and examined the candidate during open defence. This is, therefore to certify that the Thesis is accepted for partial fulfilment of the Requirements of the Degree of Master of science in Chemistry

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List of Abbreviations

AIP	Adama Industrial Park
ASTU	Adama Science and Technology University
APHA	American Public Health Association
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EEPA	Ethiopian Environmental Protection Authority
EMDFE	Ethiopian Ministry of Development, Finance and Economics
FTIR	Fourier Transforms Infrared Spectroscopy
MLD	Million Litre per Day
mg/L	Milligram per Litre
NTU	Nephelometric Turbidity Unit
Pt-Co	Platinum Cobalt Unit
pH	Potential of Hydrogen
PAC	Poly Aluminium Chloride
RPM	Revolution Per Minute
TSS	Total Suspended Solid
UNEP	United Nations Environmental Programme
WTP	Wastewater Treatment Plant
ZLD	Zero Liquid Discharge

Abstract

The textile industries generate significant textile wastewater, posing significant environmental and human health risks. The use of synthetic flocculants, which are effective in cleaning contaminants, has been criticized for its limitations, including pH issues, inefficiency, and negative effects on human health. As a result, natural materials are being explored for treatment. Therefore, the objective of this study was to evaluate the effectiveness of Cactus mucilage as a natural flocculant for the treatment of textile wastewater. The liquid form of Cactus mucilage was extracted by adding 500gm of peeled cactus mixed with 1:7 ratio of distilled water followed by maceration for 8hrs at temperature 40±2 ^{0}C and filtration using fine cloth. The Flocculation experiments were carried out using Jar-test apparatus in order to study the effect of extracted cactus mucilage as well as optimum condition of flocculation by varying some operational parameters such as dose of flocculant (0.5-3ml), pH (4-10), and mixing time (10-60), while the amount of coagulant (PAC) and de-colorant were kept constant, 250ppm and 350ppm, respectively. Moreover, the effectiveness of Cactus mucilage as a flocculant in the absence of coagulant (PAC) was evaluated. Color, Turbidity, TSS, COD, BOD, alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+} and Mg^{2+} were selected as dependent variable of the experiment to show material effectiveness and measured following APHA 2000 standard procedure. The optimum conditions for the efficient use of cactus mucilage as a bioflocculant were 2 ml of flocculant dose, pH 7, and 50 minutes of mixing time. At this optimum condition the removal efficiency in the presence of PAC and de-colorant with rapid mixing of 150rpm for 3 minutes and slow mixing of 50 rpm for 50 minutes and 20 minutes of the settling time for Color, Turbidity, TSS, COD, BOD, alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+} and Mg^{2+} were 98.6%, 98.2%, 98.6%, 79.8%, 72%, 34.6%, 37.4%, 96.8%, 70%, 31.3%, 42% and 39.8%, respectively from textile Wastewater. Hence, the uses of Cactus mucilage as flocculant in the presence of PAC and decolorant is found to be effective for removal of aforementioned parameters.

Key words: *Flocculation, Bioflocculant, Textile Wastewater and Cactus mucilage*

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Textile industries are one of the largest water consumers and polluters industry. High suspended solids, chemical oxygen demand, heavy metals, color, acidity, and other soluble substances are the main contaminants in textile wastewaters (Adel et al., 2005). The process-generated waste water is released into the water streams. Therefore, the harmful contaminants in that effluent mix with the water streams and represent a threat to the environment and people, particularly through the food chain. As a result, we must concentrate on processing textile waste before releasing it into the environment (Vashi, 2013).

In Ethiopia textile sub-sector played promising role in industrial development and is given much more attention by the Ethiopian government (Ministry of Development, Finance and economics 2010). However, there is common practice to release partially or fully untreated wastewater directly into the environment. This textile effluent is highly colourful, salty, and contains non-biodegradable chemicals that make the sector as one of the dirtiest industry and cause series environmental damage in the developing countries. This is besides of the high-water consumption in the process. Thus, a continued search for suitable methods (low cost, highly efficient, locally available, and environmentally friendly) to treat wastewater from the textile sector has been prompted to sustain and make the sector competent (Ghebremechael 2004)

Coagulation-Flocculation method is one of the important separation processes that are extensively employed in wastewater treatment (Mohammad A. et al., 2017). Various types of flocculants have been developed and marketed to meet requirement of major quality parameters such as suspended solid, turbidity, chemical oxygen demand (COD) and color through sedimentation. They have been applied in diverse range of wastewater such as food and beverages, paper manufacturing, agricultural production, textile, municipal and others. (Lee C. et Al., 2014). In the coagulation process destabilising of contaminants occurred and through addition of different dose of flocculant finely suspended or dispersed particles are aggregated together to form flocs into the size for speedy sedimentation and clarification (Sharma et Al., 2006)

According to their source, flocculants are primarily classified into three groups; Synthetic (Inorganic chemicals and polymers), Semi-synthetic cationized flocculant (natural polymers grafted with Synthetic polymers), and natural (Plant and microbial bioflocculant). Unlike natural flocculant, others have limitations such as affecting the pH, applied only to a few dispersed systems, inefficient to flocculate very fine particles, ineffective in low-temperature water, have detrimental effects on human health, produce large sludge volumes, and affect biomass and biomass-derived products (Sharma et al. 2006). Hence, the use of bioflocculant derived from plants and microorganisms would be a solution to avoid aforementioned problem.

Cactus is a member of the cactaceae family and found in Mexico, all of the Western hemisphere and numerous other locations across the globe including Africa, Australia, Europe and the Mediterranean region. The Family of Cactaceaes genus Opuntia contains a number of species. This includes *O.Ficus-indica, O. dilleni, O.robusta, O. tormentosa and O.tuna.* The most widespread species cultivated in Ethiopia is O.ficus-indica. In Ethiopian it is known with the local name "Qulqual'' by Amharic and "Ádamii'' by Afan Oromo. The primary reason why Cactus could be used to treat wastewater is that it has biochemical constituents that are free from hazardous effects (Zhang et al. 2005). Numerous studies have indicated that cactus contains of, polysaccharide as a major component, and has a low protein and fat content. Cactus species are distinguished by the formation of polysaccharide mucilage. It has been found that calcium ion occurs in cactus mucilage as calcium-oxalate, has a considerable influence on the mucilage molecular conformation, and boosting its water holding capacity (Saurabh et al.,2019). Furthermore, the rate of mucilage viscosity was found to be sufficient to provide the industrial needed consistence to liquid formations, particularly in suspension preparations, implying that this substance might be used as a natural flocculant in industrial wastewater treatment (Rebah S.et al 2017).

1.2. Statement of problem

Industrial pollution, particularly in the textile sector, is a major environmental concern globally. Ethiopia's textile industry contributes significantly to economic growth, but effluent discharge practices fail to meet national discharge requirements due to inadequate treatment, weak policy enforcement, and lack of awareness (Rahel Muche Kassa. (2007). Actually, there is trend of untreated or partially treated effluent from textile wastewater being discharged to the environment. This trend is not appropriate and unsustainable as it may result in major environmental problems. To solve this problem there are several techniques for treating textile wastewater; however, the majority of them are either prohibitively costly or environmentally hazardous. One of the most effective and efficient ways to treat textile wastewater is flocculation using natural flocculants. Chemical flocculants like cationic and anionic polyacrylamide, ferric salt, and synthetic polymers have also been extensively used in water purification and treatment (Mekibib Soresa. 2011). However, the toxic compounds that are released into the environment by these chemical flocculants have a negative impact on human health. Additionally, they create enormous amounts of sludge, are relatively expensive, useless in low-temperature water, and negatively impact the pH of the treated water. They also contribute to human illnesses like Alzheimer's (Beyene et al., 2017). It is vital to look for other flocculants that reduce these issues. and friendly to the environment. Therefore, the aim of this research is to develop a new flocculant using cactus mucilage, which is considered to be low-cost and eco-friendly material for the treatment of textile wastewater.

1.3. Objective of the study

1.3.1. General Objective

- ✓ General objective of this research was to evaluate treatment efficiency of Cactus mucilage on Textile wastewater as a bioflocculant

1.3.2. Specific Objectives

The Specific objectives of this research are:

- ✓ To characterize the physicochemical properties of raw and treated textile wastewater
- ✓ To prepare Cactus mucilage and characterize its functional and selected physical properties.
- ✓ To determine optimum value of flocculant dose, Contact time and pH on the performance of coagulation flocculation process with and without addition of coagulant on the removal of major parameters Color, Turbidity, TSS, COD, BOD, PO_4^{3-} and TN from textile effluents.

1.4. Scope of the Study

The purpose of this study was to evaluate the efficiency of Cactus mucilage as a flocculant in the treatment of textile wastewater. As a result, this study does not address technologies and procedures other than flocculation that may be appropriate for textile wastewater treatment. Furthermore, this study does not seek to investigate every aspect of textile wastewater. Color, Turbidity, TSS, COD, BOD, Alkalinity, F, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+}, Mg^{2+}, and pH are the parameters that are delaminated. Additional possible flocculation process considerations include the kind of flocculant employed, temperature, and the presence of additional chemicals or pollutants in the effluent. This study, on the other hand, highlights the significance of flocculant dosage, pH, agitation/mixing speed, turbidity level, mixing time, FT-IR analysis, and Cactus proximity analysis as significant components to be examined.

1.5. Significance of the Study

The purpose of this research is to introduce the use of Cactus mucilage as a natural flocculant. This natural flocculant has various advantages, including being safe for human health, ecologically friendly, locally available, cost-efficient, producing less volume and biodegradable sludge, and maintaining the pH value of treated water. The study's relevance to alleviating the textile industry's environmental challenges is fully recognized by proposing a flocculation procedure employing natural flocculants. As a result, this research will help Ethiopia develop an effective textile wastewater treatment method based on Cactus mucilage, which is critical for maintaining people's health, protecting the quality of the environment, and ultimately lowering the costs of wastewater treatment chemicals. The use of natural flocculants in the textile wastewater treatment process, such as Cactus mucilage, can also help achieve sustainable development goals by lowering reliance on synthetic chemicals. Furthermore, this study may be used as a model for other nations facing comparable environmental difficulties in the textile sector, encouraging information exchange and collaboration for global solutions.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Wastewater in Textile industry

The degradation of surface and groundwater quality caused by industrial and urban discharges has long been known. Throughout the world, rivers and streams are common recipients of industrial waste. The decrease in water quality has a negative impact on humans as well as aquatic ecosystems, either directly or indirectly (Ugochukwu, 2004). When untreated or partially treated effluent enters a body of water, it either dissolves or remains trapped on the river bed, polluting the water. Industries are induced to believe that they cannot avoid significant amounts of wastewater created during important industrial activities, and as a result, they lack initiative in pollution control (Hayelom, 2019).

The textile and apparel industry are one of the world's largest and oldest industry. The textile industry's dyes and chemicals have been discovered to differ based on the materials generated. The textile industry is particularly water-intensive; it needs fresh water for a variety of activities during the production process. In terms of the amount and complexity of waste water discharge, the textile industry is one of the most polluting sources. The waste water created by the textile industry is often warm, alkaline, strong smelling, and coloured by colouring chemicals. In general, textile companies produce 200–350 L of wastewater for 1 kilogram of completed product (Gozálvez-Zafrilla et al., 2008), resulting in an average pollution of 100 kg COD per ton of fabric (Vandana T. 2007).

Different types of dyes, synthetic chemicals used in manufacturing processes, and colors with complex compositions make up the wastewater produced by the textile sector. Additionally, because of its high solubility in water, it has a significant negative environmental impact when released into water sources. Additionally, typical textile wastewater is known to have a range of pH solutions, high temperatures, high COD and BOD demands, high suspended solids (SS), and is also distinguished by a high amount of color given by remaining colors (Hayelom, 2019).

2.2. The Production process of Textile Industry and Source of wastewater

2.2.1. Production process in Textile Industry (Textile processing)

The textile industry is made up of a diverse group of companies that manufacture and/or process goods related to textiles (such as fibres, yarn, and fabric) in preparation for further processing into apparel, home goods, and industrial items. During the numerous phases involved in textile production, textile industry facilities, in various ways, gather and organize fibres; change fibres into yarn, thread, or webbing; transform the yarn into fabric or associated commodities; and dye and finish these commodities (Ghosh P.et al.,2000).

Textile wet processing

The wet processing of textiles is an important step in the production of textiles because it gives the fabric its wonderful and useful qualities, which add the most value. Wet processing of textiles requires the use of a significant amount of water as a solvent. At the last stage, this water which is polluted with unfixed dyes, chemicals, and auxiliaries is discharged as effluent. Because they constitute a chemical mix, textile effluents are challenging to handle (Saxena et al., 2017).

Table 1: Wet textile processing and wastewater generation

Process	Wastewater contaminants
Desizing	BOD from water-soluble sizes; synthetic sizes, lubricants
Scouring	NaOH disinfectant and insecticide residue, detergents and fats
Bleaching	Hydrogen peroxide, Sodium silicate, organic stabilizer
Mercerizing	High pH chemicals, NaOH
Dying	Heavy metals, salts, surfactants, BOD, Color agent
Printing	Suspended solids, urea, solvent, color, metals, BOD
Finishing	BOD, COD, suspended solids, spent solvents

Adopted and modified from (Babu B. et al., 2007)

Sizing and Desizing

Sizing is done to give the fabric's face a smooth, uniform, and clean appearance by eliminating the loose, hairy threads from its surface. The yarn is coated throughout the size process to make it easier to weave, knit, and tuft. Chemicals, including polyvinyl alcohol, carboxymethyl cellulose, and polycyclic acids, are used to conduct sizing. The amount of sizing material in the effluent released from an average mill that generates roughly 60,000 meters of fabric is estimated to be around 750 kilograms (kg). Processes including dyeing, printing, and finishing are hampered by the presence of sizing components in the yarn. For instance, the presence of starch might prevent color from dispersing into the fibres (Council 1995).

Desizing is the process of removing the sizing ingredients that have been applied to the cloth to improve the yarn's strength. Without being desized, fabric is stiff and difficult to handle during the following procedures. Starch is detached or changed into a water-soluble state during the desizing process, either by hydrolysis or by oxidation (Batra 2017). Approximately half of the entire wastewater volume, which has high levels of biological oxygen demand (BOD), is a result of the desizing process. The issue can be solved by using enzymes that can convert starch into straightforward ethanol rather than complicated anhydroglucose. It is also possible to use an oxidizing agent, such as hydrogen peroxide (H_2O_2), to completely dissolve starch into carbon dioxide (CO_2) and water (H_2O) (Babu B 2007).

Table 2: Ecological friendly unconventional chemicals for textile wet processing

Purpose	Convectional chemicals	Alternative chemical
Sizing	Starch	Water-soluble polyvinyl alcohol
Desizing	Hydrochloric acid	Amylase
Scouring of cotton	Sodium hydroxide	Pecrinase
Bleaching	Hypochloride	Hydrogen peroxide
Oxidation of vat and sulfur dyes	Potassium dichromate	Hydrogen peroxide
Thickener	Kerosene	Water-based polyacrylate copolymer
Hydrotropic agent	Urea	Dicyanamide
Water repellent	C_8 fluorocarbons	C_6 fluorocarbons
Wetting agent	Alkyl phenol ethoxylates	Fatty alcohol phenol ethoxylates
Neutralization	Acetic acid	Formic acid
Mercerization	Sodium hydroxide	Liquid ammonia
Reducing agent	Sodium sulfide	Glucose, acetyl acetone
Dyeing	The powder form of sulfur dyes	Per-reduced dyes

(Adopted and modified from (Arputharaj et al., 2016))

Scouring

Scouring is a chemical washing procedure used on cotton fabric to remove any more dust or dirt as well as any natural wax and non-fibrous impurities (such as seed pieces) from the fibres. An alkali solution is used to boil the cloth, creating soap with free fatty acids. In this process, hot alkali, detergent, or soap solutions, such as glycerol, ethers, and scouring solvents, separate cotton wax and other non-cellulosic components of cotton (Madhu A. et al., 2017). Sodium hydroxide (NaOH), detergents, insecticide residues, pectin, fats, oils, and wax, spin finishes, knitting lubricants, spent solvents, and scouring can all be used to add significant organic loads to textile effluents. Scouring can be done in batch or continuous processes. These effluents have a pH of 10 to 11, which is quite alkaline (Keerthi G. et al., 2012).

Bleaching

By reducing the cotton's remaining residual impurities and natural color, bleaching enhances the whiteness of the fabric. The yarn's inherent coloring gives the cloth a creamy look. To obtain white yarn that will enable the creation of light and bright hues, the yarn must first be dyed by bleaching (Madhu A.et al., 2017). One of the earliest industrial bleaching agents was hypochlorite. Today, absorbable organ-halides are further employed as bleaching agents. Using absorbable organically bound halogen (AOx), the formation of very harmful chlorinated organic by-products during the bleaching process can be reduced. Additionally, peracetic acid (CH3CO3H) is a risk-free substitute for hypochlorite. Using CH_3CO_3H results in higher brightness ratings with less fiber damage. Recently, one-step preparatory desizing, scouring, and bleaching treatments have reduced the quantity and toxicity of the effluent (Slokar Y. 1998).

Mercerization

Mercerizing is a process that gives cotton fabric and threads a glossy sheen and increases their tensile strength. Cotton and other cellulosic materials are subject to the procedure. Fabric is treated with a sodium hydroxide solution during mercerizing to cause the fibres to swell. Strength and dye affinity are therefore enhanced. After bleaching, cotton fabric and fibres are mercerized in their grey condition to add sheen, boost strength, and improve colour absorption. During the mercerization process, cotton textiles are exposed to a strong (18–24%) caustic soda solution for 1–3 minutes before being washed clean. When cotton is handled with this solution, longitudinal shrinkage might happen. In order to prevent shrinking, the fibres or textiles are maintained under stress during this operation. The fabric and fibres obtain the required characteristics of luster, improved strength, dye intake potential, and amplified absorbency. Membrane techniques may be used for the recovery of NaOH present in the wash water. The use of zinc chloride ($ZnCl_2$) is another way to increase the fabric's weight, accelerate dye intake, and permit the easy recovery of NaOH. This practice does not need neutralization, and thus, it is environment-friendly (Karim M. et al., 2006).

Dyeing

The process of dying involves giving textile items like fibres and yarns color. Typically, dyeing is carried out in a customized solution that contains dyes and a specific chemical. Following dyeing, the chemical link between the dye and fibre molecules is no longer disrupted. The two main elements that influence this process are temperature and time. Chemical pigments (dyes) are added to fibres or cloth during the dyeing process to create colors. Synthetic dyes, which mainly come from coal tar and petroleum industry by-products, are most frequently employed in the textile industry. In synthetic dyes, auxochromes, an electron-withdrawn or electron-donating substituent, are in charge of the exaggeration of the color, while chromospheres, the atoms, are responsible for the color. To improve dye adsorption onto the fibres, a variety of chemicals, including formaldehyde, heavy metals, surfactants, salts, and sulphide, may be added. These compounds are major pollutants in the dyeing process effluent (Sarayu et al., 2012).

Water is used in the dyeing process to transport colours in steam form and warm the treatment baths. For wet processes, the dyeing of cotton fibre requires enormous amounts of water. For instance, to dye 1 kilogram of cotton using reactive dyes, 0.6 to 0.8 kg of sodium chloride (NaCl), 30 to 60 grams of dyestuff, and 70 to 150 litres of water are needed (Jyotshana S. etal.,2021). Following the dying process, a range of colorful dye baths with high salt and organic component concentrations are discharged. Dye baths are typically quite polluted. For instance, 20 to 30 percent of the reactive dyes in wastewater created during reactive dyeing are hydrolysed reactive dyes that are not attached to the textile materials. The various hues of the dyeing process' effluents can be attributed to these leftover dyes. Recycling organic materials or coloring agents is not possible. As a result, their addition to effluents causes the effluents' high BOD and chemical oxygen demand (COD) (Babu et al., 2007).

Printing

The term "localized dyeing" refers to a branch of dyeing that includes printing. In printing, certain portions of the cloth that make up the design are dyed. Printing and dyeing both entail necessary chemical processes. Color is applied as a thick paste of the dye in printing, whereas color is utilized as a solution in dyeing. The most popular chemically reactive dye used in printing, urea, has a significant pollution burden (Babu et al., 2007). Recently, screen-free printing methods have developed that are more environmentally friendly than these other methods, such as electrostatic printing and ink jet printing (Lukanova V. et al., 2005).

Finishing

All bleached, dyed, printed, and certain grey textiles go through a series of steps called finishing before being sold. The goal of textile finishing is to make products suitable for their intended use or purpose and/or to increase the fabric's usability. Applying one or more finishing techniques to fabric may result in a significant increase in value. Both natural and synthetic fibre textiles require a variety of finishing activities to be processed. Finishing entails applying a variety of finishing chemicals made for cross-linking, softening, and waterproofing in order to generate certain qualities in the refined fabric. The use of biocides finishing chemicals gives finished textile fabrics specific antimicrobial properties and protects finished goods from microbial deterioration (USEPA 1997). Biocides are mostly inorganic or organ synthetic compounds that are used to sterilize, sanitize, or disinfect objects in order to maintain them or guard against microbial deterioration. The fundamental connection between textile biocides and toxicity in dye house effluent Similar to that, color carriers also make textile effluents more hazardous than other effluents (Arslan A. 2007).

2.2.2. Source of wastewater

Water used for cleaning, preparation, dyeing, finishing, non-contact cooling, and other processes are often the major sources of effluent. Depending on the mill, processes, tools, and materials produced, the industry's water usage varies greatly. Each textile manufacturing process uses a significant quantity of water, which eventually turns into wastewater (Teshale et al., 2021).

The pretreatment, dyeing, printing, and finishing of textile materials are among the major production phases' most important producers of wastewater. Desizing is the primary source of wastewater in the business during the pretreatment stage (National safety council 1995). All the sizes used during weaving are taken out of the cloth during desizing and discharged into the wastewater. Scouring removes dirt, oil, and waxes from natural fibers in the garment and flushes them into the wastewater stream. Desizing and scouring are frequently coupled, and the combined effects of these two processes may account for 50% of the BOD in the wastewater after wet processing. The peroxide bleaching wastewater is not a significant issue. (De Forion L. et al 2005). The majority of the overall effluent is produced by the dyeing process. Wastewater is produced during the dye preparation, wasted dye bath cleaning, and washing operations. Wastewater from dyeing has a high salt, alkalinity, and color content. Organic contaminants caused by finishing procedures, such as resin, softener, and other auxiliaries residue, are produced. (Legrine O. et al., 1993). A textile mill's effluent is often produced at high pH, temperature, detergents, oil, suspended and dissolved particles, dispersants, leveling agents, hazardous and non-biodegradable materials, color, and alkalinity levels. (Muralimoham N. et al., 2004).

2.3. Characteristics of Textile Wastewater

Different textile effluents have different characteristics that rely on the type of raw materials used, the chemicals used, and the type of cloth produced (Ejeomo C. et al., 2013). High levels of pollutants that harm the environment and human health are present in the textile wastewater, including suspended and dissolved particles, biological oxygen demand, chemical oxygen demand, heavy metals, odor, and color (Ghaly AE. Et al., 2004). Several BOD/COD ratios have been found to be around 1:4 which implies the presence of non-biodegradable materials. A textile industry's effluent is typically characterized by dangerous swings in a variety of parameters, including COD, BOD, pH, color, and saltiness. (Mekibib Soressa 2011). The many organic-based substances, chemicals, and colors employed in the dry and wet processing phases will determine the wastewater's composition. (Venceslau M, C et al., 1993).

2.4. Environmental Impact of Textile Wastewater

Textile industries are thought to hold the top ranking in terms of wastewater volume produced and composition. There are significant issues with the incorrect and careless dumping of textile effluents in natural rivers as well as land (Mekibib Soressa 2011). The organic and inorganic chemical constituents found in textile effluent are harmful to water purity and the development of all plants and animals. Every stage of the textile industry's life cycle has seen environmental effects as a result of its chemical-intensive nature as applied to various operations (Vinod Kumar et al., 2012).

Recent research has indicated that the widespread use of organic dyes with complex and highly diverse chemical structures is the primary cause of environmental issues connected to textile-related activities (Carliell M. 1993). In addition to giving water an unpleasant hue, dyes can irritate the skin and lungs and induce migraines, congenital abnormalities, nausea, and hemorrhages. They could prevent sunlight from penetrating through water's surface, which would stop photosynthesis. Additionally, dyes cause the receiving water's biochemical oxygen demand to rise, which slows down the re-oxygenation process and prevents the growth of photoautotrophic organisms (De Florio L. et al., 2003). Additionally, the aquatic flora and wildlife are impacted by the dye that is released with the effluent into receiving waters. Some colors are carcinogenic, while others produce poisonous substances such aromatic amines after being transformed or degraded (Mekibib et al., 2011).

Additionally, dyes build up in sediments at various locations, particularly near where wastewater is discharged, which affects the biological balance in the aquatic system. These contaminants damage the ground water system due to soil leaching (Patel H, Vashi R.T 2013). Color is the first pollutant that can be identified in dyeing effluents; hence it must be eliminated before discharge into the receiving environment. Similar to inorganic compounds, textile effluents include an excess number of soluble salts that render the water unfit for usage. Even in small amounts, it has been discovered that these compounds are harmful to aquatic life (Ministry of Finance and Economic Development, 2010).

Due to their interaction with greasy slime and disruption of the oxygen transfer process at the air-water interface, the suspended material concentrations in effluents have a significant impact on the environment (Farah Maria et At., 2013). Additionally, the release of organic pollutants like COD or BOD into the receiving stream may cause the dissolved oxygen to be depleted, which will result in anaerobic conditions. Hydrogen sulfides and other strong-smelling compounds can be formed in anaerobic environments. As a result, the biological activity in the receiving stream will be disturbed. Additionally, the textile mills produce wastewater that contains harmful heavy metals including cadmium, chrome, lead, nickel, and zinc, among others (Mekibib et al., 2011).

Heavy metals are present in water used for irrigation that contains textile waste, which accumulates in various plant sections and causes a variety of health problems in both humans and animals via the food chain (Ghaly A. et al., 2004). The accumulation of heavy metals in the effluent increases the potential that they may enter the food chain (Pala, A 2011). In both cases, the inorganic heavy metals are taken in immediately by the freshwater and marine life or are incorporated into the groundwater, meaning that the heavily consumed marine foods and contaminated groundwater may cause diseases like cancer, tumors, brain and liver diseases, psychiatric illnesses, and sexual diseases (Ejeomo C. et al., 2013). In conclusion, textile wastewater has negative environmental effects. Due to many factors, Ethiopia is predicted to have a high level of this consequence. In place of using waste treatment, there is a tendency to dump industrial effluent directly into aquatic bodies or land (Achi O. K. et al., 2011).

2.5. Textile Wastewater Disposal Standards

There are several methods for treating textile wastewater, but the majority of them are too expensive for enterprises of all sizes to adopt. Many physico-chemical technologies also don't offer a long-term solution to the issue since they just change the forms or phases of the contaminants (Rahel M. et al., 2007). Around the world, a variety of environmental protection agencies have put restrictions in place to safeguard the environment and public health from pollution caused by the textile industry. These organizations establish guidelines for the release of effluents into the environment (Ghaly A. et al., 2004). The challenges of disposal have been observed to vary by area. Monitoring these discharge restrictions on a regular basis is vital to maintaining a safe and healthy ecosystem. In order to safeguard depleted natural water resources, industries must instantly monitor textile effluents on a continuous basis and take the required actions to properly remove the wastewater before dumping it into water bodies (Ejeomo C et al., 2013).

2.6. Textile Wastewater Treatment Methods

Due to the variety of raw materials, chemicals, processes, and technical improvements employed in those activities, the textile industry's impact on the environment is complex and dynamic (UNEP, Textile Industry and Environment). Different contaminants have varying amounts in textile wastewater, depending on the wastewater treatment methods used and the volume of water used in the manufacture (Pala, A., 2001). Therefore, it is crucial to implement an efficient treatment strategy. There are several ways to remediate textile wastewater. Different plants will have unique combinations of techniques that are effective depending on the size, kind, and amount of therapy needed. The three main treatment methods used to treat wastewater from the textile industry are biological, physical, and chemical methods (Debbie De Jager 2013). Regarding the complexity of textile wastewater, a number of parameters, including dye type, wastewater composition, chemical dose and cost, operating expenses, environmental destiny, and handling costs of created waste products, influence each treatment option's technical and financial viability (Van Der Zee. 2002).

2.6.1. Biological Methods

Different biological therapeutic modalities exist. Activated sludge, aerobic and anaerobic processes, sequencing batch reactors, oxidation ponding, and trickling filters are a few examples (Pala, A., 2001). The developed activated sludge system and conventional processes make up the majority of biological processes. After initial settling, the wastewater in the activated sludge process enters a tank. Aggregates of the microorganism found in activated sludge are suspended in the wastewater. Compressed air maintains the suspension of the sludge and wastewater and also provides the oxygen required for biological activity. A part of the sludge from the continual removal and settlement of the aerated waste is added back to the influent. Typically, approaches include oxidizing organic waste utilizing a natural process involving bacteria and other microorganisms to remove contaminants from wastewater. Biological approaches are routinely utilized to remove organic and color from dyeing and textile effluent because they are often inexpensive and easy to use (Arshad Husain et,al, 2013). Because many industrial dyestuffs are poisonous to the organisms being utilized and produce the issues of sludge thickening, rising sludge, and pin flock, biological treatment techniques are typically ineffective for treating dyestuff effluent. (Arshad Husain et,al, 2013). Because of the toxicity of the wastewater and the requirement for an aeration system, biological treatment of dyeing wastewater is less expensive than other procedures but less effective for color removal (Sapci Z and Ustun B, 2003)

2.6.2. Physical Methods

Reverse osmosis, membrane filtration, and adsorption are examples of physical methods. Adsorption is a useful technique for reducing the number of dissolved dyes in the effluent, which removes color. Without pretreatment, suspended particles quickly block the filter, making it unable to adsorb on activated carbon. Therefore, only a biological treatment or a flocculation-decantation therapy in conjunction with this process is practical. Activated carbon is expensive, but the combination allows for a decrease in organic and suspended particles as well as a small lightening of color. Pollutant removal from wastewater may be accomplished through membrane filtering. But the initial investment cost is quite high, and the expense of replacing the membrane on a regular basis is surprisingly significant. The removal of macromolecules and particles is possible using ultrafiltration (Verma et al., 2012).

2.6.3. Chemical Methods

Coagulation, flocculation, oxidation, and other processes are included in the process. Although successful, the majority of chemical treatment approaches have been studied with an emphasis on color removal since they are costly or may result in additional secondary pollutants. The greatest immediate solution for undeveloped areas lacking good wastewater treatment infrastructure is to adopt straightforward, reasonably priced point-of-use technology like coagulation. The process of coagulation is crucial to the treatment of industrial effluent. Chemical oxidation forces the breakdown of refractory organic pollutants by using potent oxidizing agents like chlorine, hydrogen peroxide, and others. Due to its simplicity, chemical oxidation is the most commonly used technique for color removal by chemicals. Hydrogen peroxide is the primary oxidizing agent. Chlorinated hydrocarbons, phenol, insecticides, and aromatic hydrocarbons can all be degraded by ozone oxidation. One of the main benefits of Ozonation is that it reduces the amount of sludge and effluent (Verma et al., 2012). Table 3: presents the pros and cons among the major textile wastewater treatment methods.

Table 3: Pros and cons of textile wastewater treatment methods

Process	Advantages	Disadvantage
Biodegradation	Rates of elimination by Oxidizing substance about 90%	Low Biodegradability of dyes
Coagulation-Flocculation	Elimination of in soluble dyes	Production of sludge blocking filter
Adsorption on Activated Carbon	Suspended solids and organic substance well reduced	Cost of activated carbon
Ozone treatment	Good decolonization	No reduction of COD
Electrochemical process	Capacity of adaptation to different volumes and pollution loads	Iron hydroxide sludge
Reverse Osmosis	Removal of all mineral salts, Hydrolyzes reactive dyes and chemical auxiliaries	High pressure
Nano-filtration	Separation of Organic compounds of low molecular weight	Require high cost
Ultra-filtration-microfiltration	Low pressure	Insufficient quality of he treated wastewater

2.7. Flocculation Method

Different substances, such as suspended diameter larger than 10^{-6} m to 10^{-9} m, colloidal between 10^{-6} m to 10^{-9} m, and dissolved solids diameter smaller than 10^{-9} m to 10^{-6} m are found in industrial wastewater and must be eliminated before release. These particles are unable to settle or be separated using regular physical techniques (such as filtration or settling) due to the nature of the colloidal suspension until they are agglomerated by coagulation and flocculation. One of the most frequently used unit operations in water and wastewater treatment is this procedure. The instability of colloidal particles during the flocculation process is caused by the addition of a chemical reagent called a flocculant (Metcalf, Eddy, 2003).

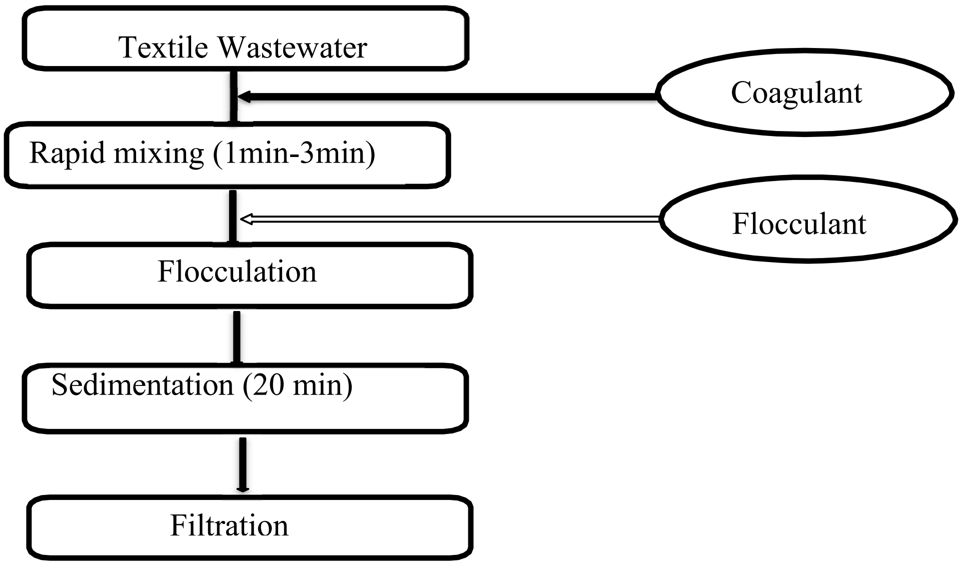

Figure 1: Steps of Coagulation flocculation process

Destabilized particles clump together to form microfloc, which eventually develops into large floccules that may be settled and are referred to as floc. The coagulation-flocculation process typically involves destabilizing colloids, aggregating them, and binding them together to form flocculates. The resultant flocs can then be removed by settling or flotation. The three main processes in wastewater treatment systems are flocculation, coagulation, and filtration (Karoliny, Souza, & Almeida, 2018). This method involves dosing a flocculant into the water, which causes the water to become unstable. In order to defeat the forces that keep the suspended particles stable and enable particle collusion and floc development, it happens in a series of phases. Destabilizing the particle charges in the water is the initial stage in the coagulation process. To balance the negative charge on the distributed non-settable solids, coagulants of opposing charges were applied. The smaller particles can bind together to create a somewhat bigger particle after the charge has been neutralized.

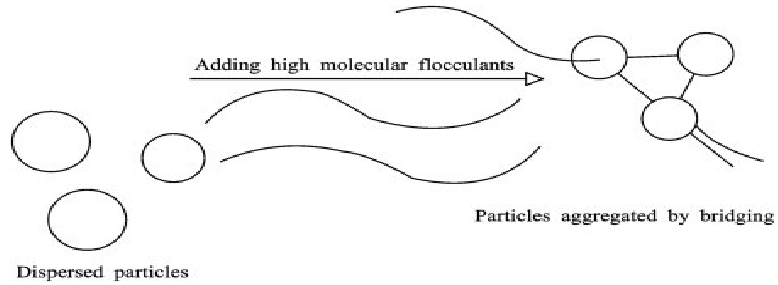

Figure 2 Schematic diagram of Coagulation flocculation process

2.7.1. Types of Flocculants

Flocculation is a solid-liquid separation step in downstream processing that has been extensively studied and applied in a wide range of industries, including food and beverage, paper manufacturing, mining, brewing, agricultural production, dyes or textiles, and municipal sewage treatment (Pal et al. 2009). Finely suspended or dispersed particles are aggregated together with the addition of flocculant to form flocs of the appropriate size for rapid sedimentation, clarification, and separation from the bulk medium. Finely suspended or dispersed particles are aggregated together with the addition of flocculant to form flocs of the appropriate size for rapid sedimentation, clarification, and separation from the bulk medium.

Flocculants

Synthetic	Semi-synthetic	Bio-flocculant
Inorganic salts	Conjunct	Plant biopolymers
(e.g., $AlCl_3$, $FeCl_3$)	(e.g., $Al_2(SO_4)_3$ + Okra mucilage)	e.g., M.*Olifera and* okra
Conjunct	Grafted	Catonized plant biopolymers
(e.g., $Al_2(SO_4)_3$ +Zeetag-7650)	(e.g., CHPTAC + Guar gum)	(e.g., Starch, insulin, tannin)
Polymer		Macrobial- based
(e.g., poly-acrylamide)		(e.g., bacterial ɤ-PGA, fungi)

Figure 3 Types of flocculants with examples (Chatsungnoen and Chisti 2016)

Flocculants are broadly classified into three types based on their origin, synthetic flocculants (inorganic chemicals and polymers), semi-synthetic cationized flocculants (natural biopolymers grafted with a synthetic polymer), and natural (plant and microbial bio-flocculants) as shown in

Figure 3. The most widely used flocculants are inorganic chemicals which include salts of multivalent metals like Aluminium and iron, namely, $Al_2 (SO_4)_3$, $AlCl_3$, $FeCl_3$, $FeSO_4$, and polyaluminium chloride (PAC) (Granados et al., 2012)

In the past, inorganic flocculants were often utilized because of their advantages in terms of efficiency, affordability, use, and availability. However, the uses of inorganic flocculants is declining because they negatively impact pH, only work in a small number of dispersed systems, are ineffective in low-temperature water, have negative effects on human health, produce large volumes of sludge, and have an impact on biomass and products derived from biomass (Sharma et al. 2006).

2.7.2. Factors Affecting the Effectiveness of Flocculant

The effectiveness of the flocculation is influenced by factors such as wastewater type, initial turbidity, temperature, physical and chemical characteristics of flocculant, pH of the solution, the type and dosage of flocculant, mixing speed and time, settling time and etc (Mohd Ariffin et al., 2008). The coagulant dose is one of the most important parameters that have been considered to determine the optimum condition for the performance of flocculant in coagulation-flocculation process (Himanshupatel et al., 2012). Essentially, insufficient dosage or overdosing would result in the poor performance in process. There is a range of optimum doses for a flocculant at which maximum settling and removal of pollutants is most effectively achieved. Below this range, the amount of flocculant added is inadequately to destabilize the particles. Above this range, the flocculant essentially serves as a chemical coating which re-stabilizes the particle (Pate H. et al., 2013).

The pH is also the second important parameter that has been considered to determine the optimum condition for the performance of treatment. In flocculation process pH will not only affect the surface charge of flocculant, but also the degree of stabilization of the suspension. Besides, pH seems an interesting variable which has a greater influence on the pollutant's removal efficiency (Pallavi N. et al.,2013). In addition to flocculant dose and pH, the effect of mixing time also plays an important role on flocs formation and growth in coagulation-flocculation process (Safiullah S et al., 2012). The time of macrofloc formation (flocculation time) is one of the operating parameters that is given great consideration in any water and wastewater treatment plant that involves coagulation (Sapci Z. et al., 2003).

2.8. Application of cactus mucilage as Bioflocculant

Cactus pear (*Opunta ficus indica*) or prickly pear, a member of the Cactaceae family, is widely distributed in Mexico and all Western hemisphere and grows in many other parts of the world, such as Africa, Australia, Europe, and the Mediterranean basin. There are several species belonging to the genus Opuntia (Family Cactaceae). This includes O. *Ficus-indica, O. dillenii, O. robusta, O. Tormentosa and O. tuna*. Of these, *O. ficus-indica* is the most common species that is grown in Ethiopia. Cactus pear (*O. ficus-indica*) is commonly known in Ethiopia as "Qulqual". Cactus pears were largely ignored by the scientific community until the beginning of the 1980s when several studies and reports were published on their biological functions (Society, 2016).

The main factor behind the possibility of using cactus as material for waste water treatment is its biochemical composition without any toxic effects. It was reported by many studies that cactus is composed of low protein and lipid contents and polysaccharide is considered as the main ingredient. Interestingly, cactus species are known by the polysaccharic mucilage production. The presence of minerals, such as Ca^{2+} and K^{+}, is necessary for the gelatinous properties of mucilage. It was reported that calcium ion exists in the cactus mucilage as calcium-oxalate and this has strong effect in molecular conformation of the mucilage increasing its water holding capacity (Rebah et al., 2017).

Figure 4: Photographic representation Cactus pear (*O. ficus-indica*)

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Study site description

The cactus used in this study were collected from around Adama Industrial Park and wastewater samples used in this study were collected from Zero Liquid Discharge Plant of AIP. It is located 100km away from Addis Ababa city, Ethiopia. Fourier transform infrared (FTIR) spectrometer was used for examining existence of functional group (FT-IR-6600 type A, Jasco Inc., Easton, America) performed in Bahir Dar university.

3.2. Chemicals and reagents

The chemicals and reagents used in this study was analytical grade. Hydrochloric acid (High Quality laboratory Chemicals pvt. Ltd, Mumbai India), Sodium Hydroxide (High Quality laboratory Chemicals pvt. Ltd, Mumbai India), potassium bromide (High Quality laboratory Chemicals pvt. Ltd, Mumbai India), nitric acid (High Quality laboratory Chemicals pvt. Ltd, Mumbai India), Calcium Chloride (High Quality laboratory Chemicals pvt. Ltd, Mumbai India), Iron Chloride (High Quality laboratory Chemicals pvt. Ltd, Mumbai India), Magnesium Sulphate (High Quality laboratory Chemicals pvt. Ltd, Mumbai India), Sulphuric acid (High Quality laboratory Chemicals pvt. Ltd, Mumbai India), Polyaluminium chloride (Henan Aierfuke Chemicals Co., Ltd. Gujarat, India), Decolorant ENVI Color4103 (Arvind Envisol pvt. Ltd. Gujarat, India.), reagents used for TN, PO_4^{3+} and COD (Hach, Loveland, USA) sulphate test kit (Aquasol, Rakiro Bioech SYS pvt. Ltd, Mumbai India), Detergent, Cactus mucilage, Distilled water(Jourilabs, Addis Ababa Ethiopia).

3.3. Equipment and Materials

The equipment and tools used throughout the experiment was Jar test apparatus (PSI, Patel Sci. Inst. pvt. Ltd., Gujarat, India), BOD Incubator (PSI, Patel Sci. Inst. pvt. Ltd., Gujarat, India), Oven (PSI, Patel Sci. Inst. pvt. Ltd., Gujarat, India), Muffle furnace (PSI, Patel Sci. Inst. pvt. Ltd., Gujarat, India), Magnetic stirrer (2MLH, REMI Mumbai, India), weight balance (CY 223, ACZel PVT. LTD, 220±0.001gm, Mumbai, India), pH meter (HANNA, HI76312, Smithfield, USA), Turbidimeter (HANNA, HI98703, Smithfield USA), COD reactor, Spectrophotometer (DR3900, HACH, Loveland, USA), FTIR (FT/IR-6600 type A, Jasco Inc., Easton, America) Aquarium air-pump (AP-408A, VENUS AUQUA, India)

3.4. Sample collection

The wastewater sample was collected by using grab sampling technique, from the Equalization Tank B of the Adama Industrial Park, Zero Liquid Discharge treatment plant. Clean Plastic containers (polyethylene terephthalate (PET) were used for sample collection after cleaning with detergent, soaked in 10% of concentrate nitric acid, and rinsed with deionized water. Whereas about 1 Kg of cactus cladode was collected near to the industrial park and brought to the Zero Liquid Discharge (ZLD) Laboratory for further preparation.

Figure 5: Sampling point in Adama Industrial Park ZLD plant (Equalization tank B)

3.5. Preparation of Cactus Mucilage Flocculant

The collected Cactus cladode sample was washed by tap water and outer part of cactus Peel offed using knife. The inner part of the cactus (mucilage) was divided and about 500 g was sliced and dry at 60°C for 24 hours in Hot Air Oven and milled using Mixer-grinder into powder or dry amorphous form later used for flocculation purposes. The remaining portion 500g of nopal Cactus/peeled cactus was crushed in a blender, homogenized with water in the ratio 1:7

and macerated for 8 hrs at Temperature of 40 $\pm$ 2^{o}C then filtered through a fine cloth to form wet cactus mucilage/aqueous form. A pre-test was run to determine the effectiveness of dry mucilage/dry and wet cactus mucilage/aqueous form by applying both the dry mucilage and wet mucilage as a flocculant on sample of wastewater collected to select the form of cactus mucilage applied for further investigation. It was conducted at optimized condition following the procedure (Saurabh Deshmukh et al.,2019) and the result was shown in appendix D.

3.6. Batch Flocculation Experiment

The flocculation experiment was used the jar test apparatus consists of the batch test, accommodating a series of six beakers together with six spindle steel paddles as shown in figure 6. Before operating the jar test the wastewater samples were mixed homogenously and their initial pH were adjusted to point on which experiment were done by adding either 1M strong acid (HCl) or 1M strong base (NaOH). Then the wastewater sample of 1L was poured in to each beaker; followed by addition of the different coagulant dose (PAC) ranging from [100ppm to 350ppm from 10% stock solution were added to the beakers while dosing Decolorant (ENVI Color4103) ranging from [200ppm to 450ppm of from 10% stock solution] and agitated at various mixing time with constant speed consisting of rapid mixing 150 rpm for 3 minutes and slow mixing 50 rpm for 10, 20, 30, 40, 50 and 60 minutes to determine the optimum flocculant, coagulant and Decolorant dose (Beyene et al., 2017).

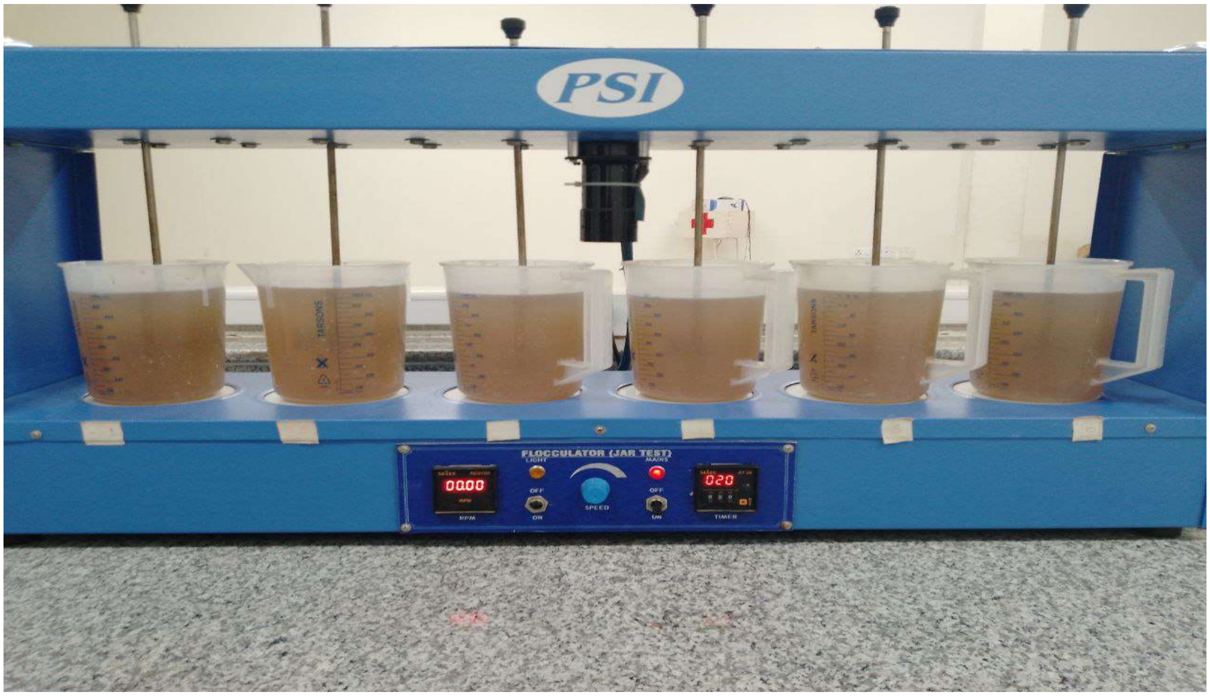

Figure 6: Photographic representation of experimental set up of Jar test apparatus

The rapid mixing disperses the coagulant uniformly throughout the beakers whereas the slow mixing promotes the formation floc by enhancing collisions of particle that led to larger flocs. After the agitation being stopped, the suspension was allowed to settle for 20 minutes, followed by filtration of the supernatant using filter papers. Then the samples of supernatant taken from each beaker were tested for Color, Turbidity, TSS, COD, BOD, Alkalinity, $F^{-,}$ PO_4^{3-}, TN, SO_4^{3}, Ca^{2+}, Mg^{2+}, and pH.

Following determination of the optimized amount of coagulant and Decolorant the batch experiment were conducted by varying some operating parameters that have prime effect on the Flocculation of textile wastewater such as flocculant dose (amount ranging from 0.5 to 3 ml in a 0.5 interval), pH (values ranges from 4`to 10), and mixing time (ranging from 10 to 60 minutes in units of 10) while other parameters kept constant and in the absence and presence of coagulant, in order to identify the optimal dosage, pH and mixing time required to obtain the best flocculant performance in coagulation-flocculation process. Optimum value of each parameter was obtained by varying the required parameter in the specified ranges while making other parameters kept constant. pH was adjusted by adding either 1M strong acid (HCl) or 1M strong base (NaOH). The details of the treatment combinations are indicated in figure 7 below:

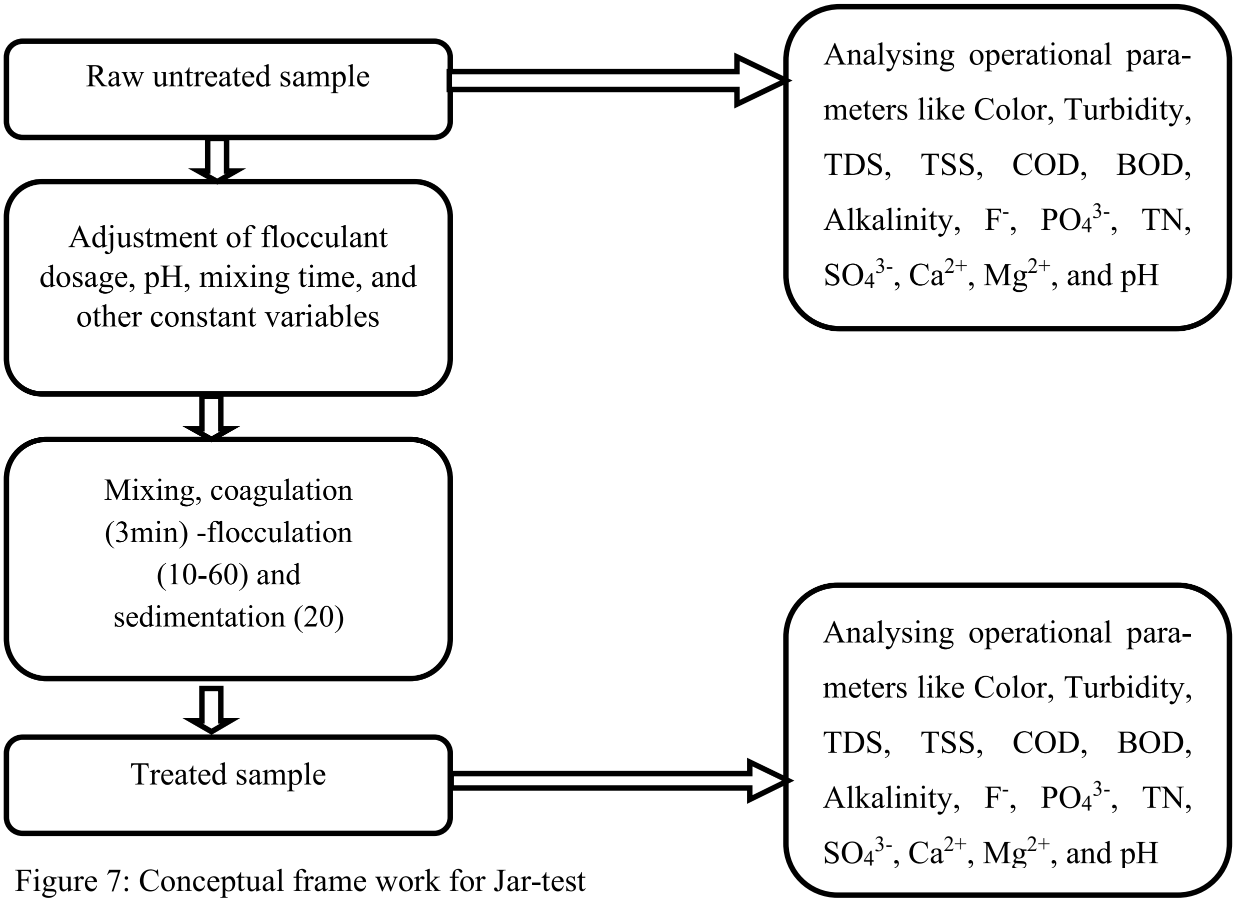

Figure 7: Conceptual frame work for Jar-test

3.7. Characteristics of Cactus mucilage

3.7.1. Determination Functional group of Cactus mucilage

The FTIR characterization was conducted in order to identify the existing functional groups of the Cactus mucilage that might be involved in the textile wastewater treatment process. It was Conducted using FTIR spectrometer (FT/IR-6600 type A, Jasco Inc., America). The Cactus sample used for the analyses was first milled using mortar and pestle to powdery conditions and the powder was mixed with KBr particles (1mg of dried sample and 100 mg of dried KBr). Mixture was pressed to a small thickness to make the pellet that is suitable to infrared analysis. Then the sample scanned in the spectrum range of 4000-400 cm^{-1}, and the type of the functional group present within the Cactus mucilage was predicted by studying the peak between particular wave numbers as shown on appendix C (Olivares P. Et.al, 2012).

3.7.2. Selected physical properties of Cactus mucilage

Proximate analysis gives an idea of determining the average of the moisture content, percentage volatile matter content, percentage ash content, and percentage fixed carbon content of the Cactus Mucilage to determine the quality of the materials. It was conducted following the procedures ASTM D5373-02 (2003) as described below.

Percentage moisture content

The percentage moisture content (PMC) was found by weighing 2g of the Cactus sample (E) and oven drying it at 105°C until the mass of the sample was constant. The change in weight (D) after mass was constant used to determine the sample's PMC using the Equation below:

$$PMC = D/E \times 100 \text{ --------------------------------------- Eq. 1}$$

Percentage volatile matter

The percentage volatile matter (PVM) was determined by using 2g of the Cactus sample in a crucible and placing it in an oven until a constant weight was obtained. The Cactus was then kept in a furnace at a temperature of 925°C for 10min and weighed after cooling in a desiccator. The PVM was then calculated using the Equation below:

$$PVM = A\text{-}B/A \times 100 \text{ -------------------------------------- Eq. 2}$$

Where A is the weight of the oven dried sample and B is the weight of the sample after 10min in the furnace at 925°C.

Percentage ash content

The percentage ash content (PAC) was also determined by heating 2g of the Cactus sample in the furnace at a temperature of 550°C for 1h and weighed after cooling in a desiccator to obtain the weight of ash (C). The PAC was determined using the Equation below:

$$PAC = C/A \times 100 \text{ --- Eq.3}$$

Percentage fixed carbon

The percentage fixed carbon (PFC) was computed by subtracting the sum of PVM and PAC from 100 as shown in the Equation below:

$$\text{Fixed Carbon} = 100\% - (PAC + PVM) \text{ ---------------- Eq.4}$$

3.8. Quality Laboratory analysis

Standard procedures of Adama Industrial Park, ZLD Laboratory were used to measure Color, Turbidity, TSS, COD, BOD, Alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+}, Mg^{2+}, and pH (APHA., 2000).

Color Measurements

A HACH spectrophotometer (DR3900, HACH, USA) were used for the Color measurements in *Pt-Co* unit. The blank (deionized water) was wiped and place it into the cell holder and the display was then showed 0 Pt-Co and, the prepared 10ml wastewater sample was wiped in to cell holder and touch read, display was then showed by Pt-Co unit. Appendix B of C shows HACH spectrophotometer (DR 3900) used for color measurement.

Turbidity Measurements

A HANNAturbidimeter (HI98703, HANNA, USA) were used for the turbidity measurements in NTU unit. The prepared 10ml wastewater sample was wiped and placed into the cell holder and run the analysis, the result was appeared in NTU unit. HANNA Turbidimeter (HI98703) used for turbidity measurement was shown in appendix B of D.

Total Suspended Solid Analysis

A HACH spectrophotometer (DR3900, HACH, USA) were used for the TSS measurements in *mg/L* unit. The blank (deionized water) was wiped and place it into the cell holder and the display was then showed 0 mg/L and, the prepared 10ml wastewater sample was wiped in to cell holder and touch read, display was then showed by mg/L unit. Appendix B of C shows HACH spectrophotometer (DR 3900) used for TSS measurement.

pH Measurements

The pH of the sample's measurements was carried out using pH meter (Model: HI5521, Manufacturer HANNA, USA). Before starting the analysis calibration of pH meter using Buffer solutions of 4.0, 7.0 and 10.0 pH meter (HI5521, HANNA, USA) used for turbidity measurement was shown in appendix B of F

COD Measurements

100 mL of sample were inserted in to blender and blended until homogenized. DRB200 Reactor was set the power to on. Pre heated to 150 °C. The cap from vials was removed for the selected

range. Clean pipet was used to add 2.00 mL of sample to the vial. Also, clean pipet was used to add 2.00 mL of deionized water to the vial. Vials were rinsed with water and wiped with a clean paper towel. After being gently mixed, the vials were immersed in the pre-heater reactor. The lid was closed. After 2 hours of heating, a reactor power shut off. The vials are removed and cooled to room temperature. The vial consisting of blank (deionized water) was wiped and placed into the cell holder, and the display then showed 0 mg/L. The vial's sample was wiped into the cell holder and touched; the display then showed in mg/L unit. Appendix B of C shows HACH spectrophotometer (model: DR3900, HACH, USA) used for COD measurement.

3.9. Data Analysis

The data collected from the above experiment were analysed using Microsoft Excel program and Originlab software. The results are presented using tables and graphs. The percentage removal efficiency of the parameters was calculated using following formula.

Removal efficiency (%) = $\frac{Co - Ce}{Co}$x 100'.................................... Eq. 5

Where, Co= Initial concentration (Before treatment)

Ce= Final concentrations (After treatment)

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Characteristics of Raw Textile Effluent

The analysis of the textile wastewater of Adama Industrial Park untreated sample revealed that the color of the wastewater was measured at 1795 Pt-Co, indicating a high level of color. Additionally, the result showed that the Ph, TSS, COD and BOD was 7.28, 287mg/L, 653 mg/L and 288mg/L respectively. These findings were consistent with previous studies conducted by other researchers, who reported similar results for pH levels ranging from 6 to 10, TSS concentrations between 150 and 1100 mg/l, COD levels ranging from 410 to 665 mg/l, and BOD concentrations ranging from 190 to 236 mg/l (Aslam et al., 2004). The presence of calcium and magnesium ions in the wastewater caused the precipitation of certain ions. The recorded levels of calcium and magnesium were 20 mg/L and 16.8 mg/L, respectively, which were consistent with findings from previous studies on calcium (13–29 mg/L) and magnesium (13–29 mg/L) concentrations. The determination of sulfate was possible due to the presence of colored wastewater, and the results indicated on sulfate concentration was 320 mg/L, which was consistent with findings from previous studies of 307–2267 mg/L. (Hussain J. and et al., 2004).

Table 4: Characteristics of raw textile wastewater emanated from Adama Industrial Park (AIP) and sampled from the Equalization Tank B

Parameters	Units	Results
PH	-	7.28
Color	(pt-co)	1795
Turbidity	(NTU)	184
TSS	(mg/l)	287
COD	(mg/l)	653
BOD	(mg/l)	288
Alkalinity	(mg/l)	260
F^-	(mg/l)	1.98
PO_4^{3-}	(mg/l)	49.9
TN	(mg/l)	12

SO_4^{3-}	(mg/l)	320
Ca^{2+}	(mg/l)	20
Mg^{2+}	(mg/l)	16.8

4.2. Characteristics of Cactus mucilage

4.2.1. FTIR result of Cactus

In order to examine the functional group that may be involved in the flocculation process of the textile wastewater, FTIR characterization was conducted. The strong stretch around 3361 cm^{-1} was due to the polymeric OH stretching vibration of water and the stretching vibration of amine. Peaks at around 2426 cm^{-1}, were due to the presence of the C=C-H group, which indicates aromatic rings and carboxylic acids, as well as OH^{-1} in a weak broad appearance. A sharp peak at around 1593 cm^{-1}, confirmed the presence of N=O stretch, N-H bend, amine group, benzene, and carboxylic acid salt. Several peaks were formed from 446 to 580 cm^{-1}, which further confirms the presence of aromatic groups. From the peak of the FT-IR spectrum, it could be evidently investigated that the major involvement of functional groups like -NH, -OH, C-O, C-H, -CH, aromatic acid, and -COOH present in the cactus. Generally, the cactus represents the characteristic frequency of functional groups associated with cactus, such as, carboxylic acid, carboxylate, ether, amine and alcohol groups. This result agrees with the study done by (Madera-Santana et al., 2018) and other literature that supports the presence of carbohydrates in the mucilage (Erica E. et al., 2010).

The principal IR absorption for certain functional groups used as reference representation in Appendix C (Olivares et al., 2012).

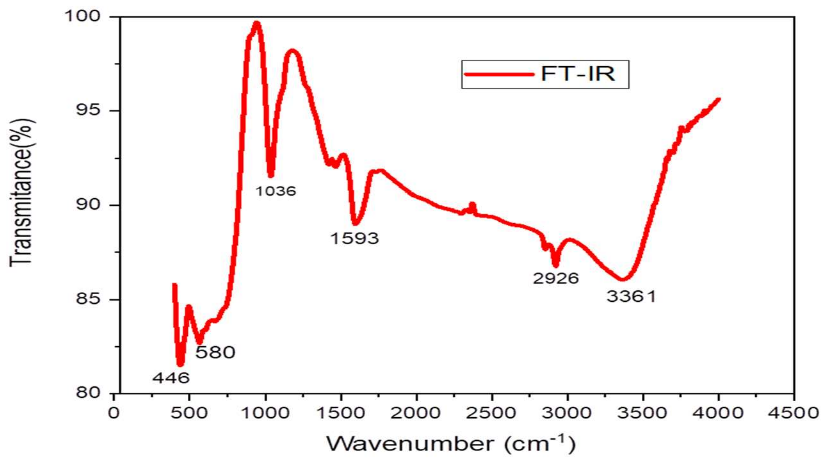

Figure 8: FTIR spectrum of Cactus

4.2.2. Results of selected physical properties of the Cactus Mucilage

The moisture and ash content of the Cactus were 4.45% and 29.87%, respectively, consistent with previous studies (E. Sepulveda et al., 2006). The moisture content was 4.9 ± 0.7, and the ash content was 34.9 ± 1.5. Dehydrated prickly pads had a similar moisture content of 4.18%. The volatile content was 64.05%, consistent with previous studies (Margarita et al., 2011). Fixed carbon, a solid combustible residue left after a Cactus is heated and volatile matter is expelled, is essentially carbon but contains minor quantities of hydrogen, oxygen, nitrogen, and sulphur. The fixed-carbon content of a Cactus is determined by subtracting the percentages of moisture, volatile matter, and ash from a sample of 100 (Junmeng C. et. al. 2017). The Cactus fixed carbon was recorded at 1.63%.

Table 5: result of selected physical properties of Cactus

Composition by %			
	Initial mass	Final Mass	Composition %
Moisture content	2g	1.911g	4.45%
Volatile	1.911g	0.687	64.05%
Ash content	1.911g	0.571	29.87%
Fixed Carbon			1.63%

4.3. Effects of Operational Parameters on Flocculation Experiment

The effects of flocculant dose, pH and mixing time are important factors in order to investigate the performance of Cactus mucilage in Flocculation process.

4.3.1. Flocculant Dose

Effect of flocculant dose in the presence of various levels of coagulant and decolorant concentration

The experiments to test the effect of flocculant dose in the presence of various concentration of coagulant and decolorant demonstrated the presence of significant removal on Color, Turbidity, TSS, COD, BOD, Alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+} and Mg^{2+} (Table 6). The result also showed as flocculant dose increase from 0.5 to 3 ml, the percent removal of measured quality parameters increased. The lowest percent removal of color (74.4%), turbidity (60.8%), TSS (65.8%), BOD (40.9), and COD (56.8%) were observed when amount of dosage was at 0.5 ml; this is because the amount of flocculant to make floc is inadequate. At the economic amount (250 ppm, PAC, 350 ppm de-colorant, and 2 ml Cactus) of independent variables inputs, percent removal of 95.3%, 98.2%, 98.6%, 75.0%, and 79.8% with respect to color, turbidity, TSS, BOD, and COD, respectively were observed.

Table 6: Quality parameter removal capacity at various focculant doses in the presence of different coagulant and decolorant concentration

Treatment	1	2	3	4	5	6
PAC (ppm)	100	150	200	250	300	350
De-colorant (ppm)	200	250	300	350	400	450
Flocculant dose (ml)	0.5	1	1.5	2	2.5	3
Parameters						
PH	7.39	7.43	7.49	7.52	7.53	7.59
Color (pt-co)	518	311	148	90	29	16
Turbidity (NTU)	74	49	17	2.93	2.19	2.13
TSS (mg/l)	98	64	18	7	0	0
COD (mg/l)	286	201	188	157	146	136
BOD (mg/l)	171	98	84.4	72.6	70	68.4
Alkalinity (mg/l)	220	200	180	170	160	150
F^-(mg/l)	1.87	1.53	1.41	1.26	1.22	1.21
PO_4^{3-}(mg/l)	26.4	11.2	4.5	1.8	0.9	0.2
TN (mg/l)	10.9	7.4	4.8	3.9	3.6	2.1

SO_4^{3-}(mg/l)	270	260	240	230	180	150
Ca^{2+} (mg/l)	16	14.1	13.5	12	9.8	8
Mg^{2+} (mg/l)	12	11.8	11.2	10.6	9.9	9.6

Moreover, percent removal of Alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+} and Mg^{2+} shows significant reduction with increasing flocculant dose. This confirms that Cactus mucilage is effective in treating textile wastewater specifically nutrients PO_4^{3-} (96.8%), and TN (70%) in which percent removal is the highest compared to other dissolved solids (table 6), and the observed pH result of the experiment showed that unlike chemical flocculants, change in Cactus mucilage dose did not have significant effect on the pH of treated effluent. Besides, pH scale of the treated effluent has fulfilled the permissive limit standard which set by EPA of Ethiopia (refer Appendix A). Thus, there is no need of pH adjustment for treated textile wastewater after flocculation using Cactus mucilage. This in turn avoids additional cost which is commonly incurred to adjust pH while using the chemical flocculant. Overall, the observed results confirmed the effectiveness of Cactus mucilage act as flocculant in textile wastewater treatment (Appendix D of III).

Effect of flocculant dose at constant Coagulant dose and Decolorant

The effect of flocculant dose at constant coagulant (PAC) 250 ppm and decolorant 350 ppm, while pH at 7 and mixing time at 50 min were kept constant, as shown in Table 7, the results showed that increasing flocculant doses from 0.5 to 3 ml led to an increased percentage removal of measured parameters. This suggests that the flocculant plays a crucial role in enhancing the effectiveness of the coagulant and decolorant. However, it is important to note that beyond a certain point, further increases in flocculant dose may not significantly improve the removal efficiency. The highest percentage removals of color, turbidity, TSS, and COD were 98.99%, 99%, 99.7%, and 79.1%, respectively, and observed at a flocculant dose of 3 ml. These high percentage removals indicate that 3 ml of flocculant is the optimal dose for achieving maximum effectiveness in removing color, turbidity, TSS, and COD. It is crucial to carefully determine the appropriate flocculant dosage to avoid unnecessary waste and ensure cost-effectiveness in water treatment processes (Appendix D of II).

Table 7: Quality parameter removal capacity at various flocculant doses while other operation parameter kept constant (pH is 7, and mixing time is 50 min)

Treatment	1	2	3	4	5	6

PAC (ppm)	250	250	250	250	250	250
De-colorant(ppm)	350	350	350	350	350	350
Flocculant dose (ml)	0.5	1	1.5	2	2.5	3
Quality Parameters						
PH	7.09	7.12	7.14	7.14	7.15	7.17
Color (pt-co)	418	206	87	39	26	18
Turbidity (NTU)	57	22	8	3.6	2.2	1.84
TSS (mg/l)	64	21	4	2	1	1
COD (mg/l)	196	184	178	161	146	137

Effect of Flocculant dose without addition of Coagulant PAC and De-colorant

In this experimental test, the effect of flocculant dose ranging from 0.5 ml to 3 ml, while pH was 7 and mixing time consisted of rapid mixing at 150 rpm for 3 minutes and slow mixing at 50 rpm for 50 minutes, and a 20-minute settling time, showed the presence of moderate removal on Color, Turbidity, TSS, and COD by removal percentages of 43.7%, 79.3%, 61.7%, and 54.9%, respectively. The results for Color, Turbidity, TSS, and COD show that the cactus mucilage is effective in lowering these parameters with moderate removal percentages. This can be explained by the fact that the cactus and the impurities in the water sample have similar surface charges (Amine E. et al., 2022). These results imply that cactus mucilage has the potential to be used as a natural and environmentally friendly water treatment alternative.

Table 8: Effect of Flocculant dose without addition of Coagulant PAC and De-colorant

Treatment	1	2	3	4	5	6
Variable	Optimum Dose without Adding PAC and De-colorant					
Cactus (ml)	0.5	1	1.5	2	2.5	3
Parameters						
PH	7.18	7.2	7.24	7.35	7.41	7.46
Color (pt-co)	1498	1333	1161	1132	1119	1112
Color removal %	24.2	32.5	41.3	42.68	43.3	43.7
Turbidity (NTU)	78	58	51.6	46	44.2	38
Turbidity removal %	57.6	68.5	71.9	75	75.9	79.3
TSS (mg/l)	234	193	144	126	115	110
TSS removal %	18.5	32.8	49.8	56.1	59.9	61.7
COD (mg/L)	512	473	364	318	305	294
COD removal %	21.6	27.6	44.3	51.3	53.3	54.9

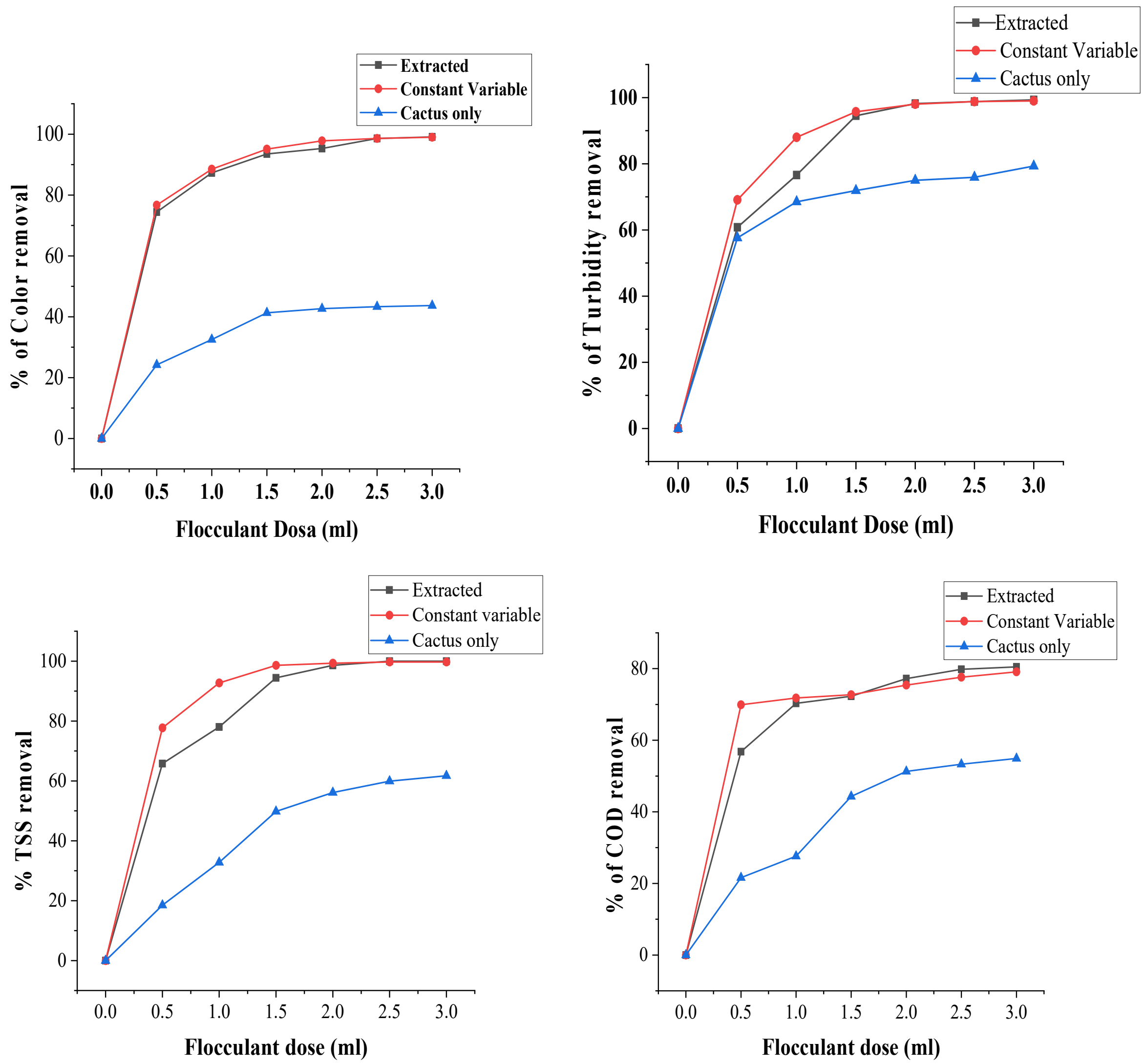

Figure 9: Percentage reduction of TSS, Color, and Turbidity and COD different form of dose of flocculant

The results presented on Figure 9 shows different effect of flocculant with presence of various levels of coagulant and decolorant concentration (Extacted), at constant Coagulant dose (250ppm) and constant Decolorant (350ppm), Flocculant dose without addition of Coagulant PAC and De-colorant (Cactus only) on percentage reduction of color, turbidity, TSS and COD by using Cactus as flocculant in flocculation process. Thus, Cactus with coagulant and decolorant have best removal efficiency than when it applied individually.

4.3.2. pH

The effect of variation in pH was analyzed at optimum dose of 2 ml and constant mixing times of 50 minute were presented in Table 9. The results revealed that the percentage removal of color (93.3%) turbidity (96.1%), TSS (95.5%), and COD (95.5%) was reached minimum at neutral condition (at pH = 7) whereas the percent removal has gradually declined as pH increase beyond 8 and decrease below 6. Similar results are also obtained in another study (Amine E. et. al., 2022). This may be due to at pH 7-point particles surface charge were reduced or neutralized as well as destabilized the suspension due to presence of PAC which is favorable condition for the flocculant, Cactus mucilage to collect those destabilized suspension. The observed minimum percent removal of color (79.9%), turbidity (89.6%), TSS (88.2%), and COD (88.2%) of the bioflocculant at pH of 10 may be due to as the pH becomes basic condition the solubility of PAC decrease that may contribute to decline charge neutralization roles of the coagulant to destabilize the particles. Moreover, at higher pH positive charges of cactus surface decreased significantly (Gobinath R. et al., 2013). Overall, at pH around 7 the result showed that flocs produced by Cactus were rapid and caused large size of flocs formation which was important for easiness of the settlement. Therefore, the Cactus mucilage is effective for the treatment of textile wastewater at neutral condition.

Table 9 Percentage removal of major quality parameters at various pH values (range varied from 4 to 10), optimized flocculant dose of 2.0 ml and constant mixing time of 50 min.

Sample / treatment	**1**	**2**	**3**	**4**	**5**	**6**
PAC (ppm)	200	200	200	200	200	200
De-colorant (ppm)	300	300	300	300	300	300
Cactus (ml)	2	2	2	2	2	2
Variable	**pH**					
Level	4	6	7	8	9	10
PH	4.58	6.17	7.08	8.33	9.42	9.94
Color (pt-co)	159	142	132	185	377	396
Color removal (%)	91.9	92.8	93.3	90.6	80.7	79.9
Turbidity (NTU)	11	9.6	7.2	12	16	19
Turbidity removal (%)	94	94.7	96.1	93.4	91.3	89.6
TSS (mg/l)	22	18	13	19	31	34
TSS removal (%)	92.3	93.7	95.5	93.4	89.2	88.2
COD (mg/l)	198	192	180	183	185	189
COD removal (%)	69.8	70.6	72.4	71.9	71.7	71.1

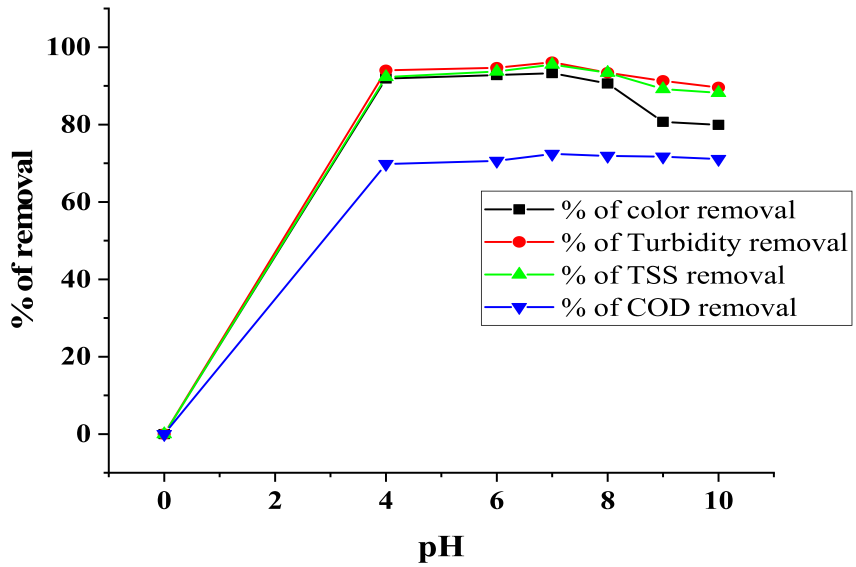

Figure 10: Effect of pH on color, turbidity, and TSS and COD percentage removal

Finally, the result of the experiment demonstrated that at pH 7 there is highest percentage removal of Color, Turbidity, TSS, COD, BOD, Alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+}, and Mg^{2+}. Therefore, Cactus mucilage is effective for the treatment of textile wastewater in neutral condition.

4.3.3. Mixing Time

The effect of mixing time on removal of Color, Turbidity, TSS, COD, BOD, Alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+}, and Mg^{2+} was tested at 2ml flocculant dose and at pH 7, which consists of rapid mixing 150 rpm for 3 minute and slow mixing time from 10 to 60 minutes with 20 minutes of settling time. When the mixing time is short (less than 50 minutes), it leads to an increase in flocs breakage and limits the size of the floc formed. It is a great importance to optimize the mixing time so as to increase removal performance of the flocculation. The minimum percentage removal was observed at mixing time was observed at mixing time 10 minutes (Color (92.3%), TSS (94.4), Turbidity (94.6), COD (73.1)) and maximum percentage removal was observed at 50 minutes (Color (93.1%), TSS (96.2), Turbidity (95.1), COD (73.7)) that is the way the optimum point of mixing time was achieved. At less mixing time minutes the coagulant and flocculants do not efficiently collide, which prevents the precipitation of suspended solids in wastewater. On the other hand, if mixing time was longer than 50 minutes, it would lead to an increase in flocs breakage and limit the size of the floc formed (Asman A. et al., 2017).

Table 10 Percentage removal of operational parameters and others at various mixing time

Sample / Treatment	**1**	**2**	**3**	**4**	**5**	**6**
PAC (ppm)	200	200	200	200	200	200
De-colorant (ppm)	300	300	300	300	300	300
Cactus (ml)	2	2	2	2	2	2
Effect of Mixing time						
Time (min)	10	20	30	40	50	60
PH	7.46	7.48	7.47	7.46	7.46	7.48
Color (pt-co)	139	136	128	123	120	126
Turbidity (NTU)	10	9.4	9	9	8	8.5
TSS (mg/l)	16	14	12	11	11	12
COD (mg/l)	184	182	182	180	181	180
BOD (mg/l)	83.5	83	83	82.1	81.8	82
Alkalinity (mg/l)	180	180	180	180	180	180
F^-(mg/l)	1.42	1.41	1.41	1.38	1.38	1.4
PO_4^{3-}(mg/l)	4.6	4.5	4.4	4.3	4.2	4.3
TN (mg/l)	4.9	4.8	4.8	4.5	4.4	4.7
SO_4^{3-}(mg/l)	250	240	240	230	230	220
Ca^{2+} (mg/l)	13.8	13.2	13	12.5	12.5	12.2
Mg^{2+} (mg/l)	11.7	11.6	11.5	11.5	11.3	11.2

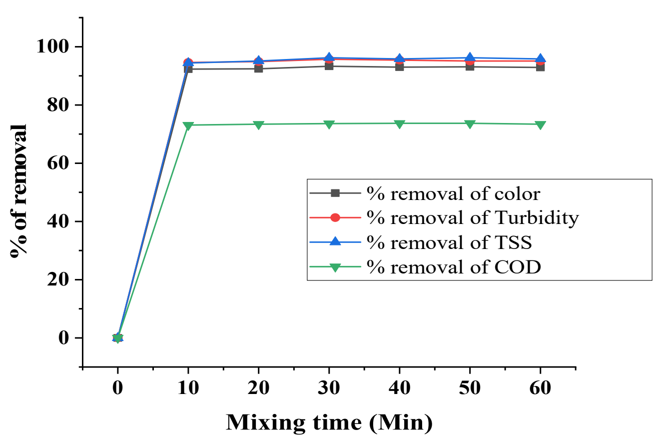

Figure 11: Effect of mixing time on color, turbidity, and TSS and COD percentage removal

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The removal of TSS, Color, Turbidity, COD, BOD, Alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+} and Mg^{2+} from textile wastewater has been done using Cactus mucilage. This study indicated that it is critical to treat textile wastewater before disposal to protect the safety of our environment. Flocculation, as used in this research, is a strong treatment strategy for contaminants in textile wastewaters. As a result, many sorts of experiments were conducted to address each of the study specific objectives. The initial character of the textile wastewater sample showed TSS-287mg/L, Color-1795(pt-co), Turbidity-184NTU, COD-653mg/L, BOD-288mg/L, Alkalinity-260mg/L, F^--1.98mg/L, PO_4^{3-}-49.9mg/L, TN-12mg/L, SO_4^{3-}320mg/L, Ca^{2+}-20, and Mg^{2+}-16.8. This shows that the textile wastewater was highly polluted, high suspended solid, highly coloured.

The flocculation experiment proved flocculant dose, pH, and mixing time to be important operating parameters for the removal of Color, Turbidity, TSS, COD, BOD, Alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+}, and Mg^{2+} from textile wastewater using cactus mucilage as a flocculant and their optimum conditions were 2 ml of flocculant dose, pH 7, and 50 minutes of mixing time. At these optimal conditions, the removal efficiency of Color, Turbidity, TSS, COD, BOD, Alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+}, and Mg^{2+} was 98.6%, 98.2%, 98.6%, 79.8%, 72%, 34.6%, 37.4%, 96.8%, 70%, 31.3%, 42%, and 39.8%, respectively. The FTIR study also confirmed the presence of various functional groups that are responsible for the flocculation process.

In general, Cactus mucilage is an effective flocculant with the capacity to significantly reduce the level of operating parameters in textile industry effluent. As a result, the encouragement and growth of flocculants provide several benefits for developing nations such as Ethiopia, including being cost effective and friendly to the environment.

Finally, from this study, we can conclude that the removal efficiency of the Cactus mucilage was very good in the treatment of textile waste water for TSS, Color, Turbidity, COD, BOD, Alkalinity, F^-, PO_4^{3-}, TN, SO_4^{3-}, Ca^{2+}, and Mg^{2+}.

5.2. Recommendations

Based on findings, the researcher suggests that Cactus mucilage be widely used as a flocculant for the treatment of textile industrial wastewater in Ethiopia. Because, for one thing it is possible to produce Cactus locally and another thing its application as flocculant should be encouraged since it is environmentally friendly flocculant. To that purpose, the following points must be addressed:

- ❖ It is recommended to use Cactus mucilage as a flocculant since it has a high potential for removing TSS, Color, Turbidity and COD from textile industry effluent.
- ❖ Future study should be conducted utilizing this technology in combination with other cost-effective treatment approaches for additional treatment in order to increase the system's removal efficiency.
- ❖ Additional research should be undertaken to determine other operational variables that may impact the efficiency of cactus mucilage as a flocculant in the treatment of textile wastewater.
- ❖ More study should be done the industrial scale application of Cactus mucilage for textile wastewater treatment.
- ❖ It is important to spread awareness among farmers to plant and engage in the Cactus tree growth throughout the nations as well as to build markets for local people to sell the mucilage.

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Appendices

Appendix A: Textile Wastewater Disposal Standards (Environmental Protection Authority)

The manufacture and finishing of textiles

Limit Values for Discharges to Water

Parameter	Limit Values
Temperature	40^0C
pH	6–9
BOD_5 at 20^0C	50 mg/l
Total nitrogen (as N)	40 mg/l
COD (mgO_2/l)	150 mg/l
Total phosphorus (as P)	10 mg/l
Suspended solids	30 mg/l
Total ammonia (as N)	20 mg/l
Oils, fats & grease	20 mg/l
Phenols	1mg/l
Mercury (as Hg)	0.001mg/l
Nickel (as Ni)	2mg/l
Cobalt (as Co)	1mg/l
Lead (as Pb)	0.5mg/l
Antimony (as Sb)	2mg/l
Tin (as Sn)	5mg/l
Chromium (as Cr VI) Chromium (as total Cr)	0.1mg/l 1mg/l
Arsenic (as As)	0.25mg/l
Cadmium (as Cd)	1mg/l
Zinc (as Zn)	5mg/l
Copper (as Cu)	2mg/l
Mineral oils (Interceptors)	20 mg/l

Appendix B: Photographic Representation of laboratory work

A. Photographic representation of before and after treatment of textile wastewater

B) Photographic representation of me while doing Jar-test

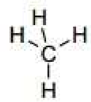
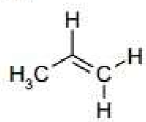
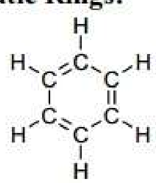
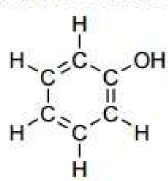
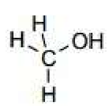
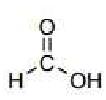
C) HACH spectrophotometer (model DR 3900)

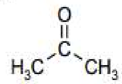
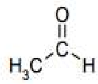
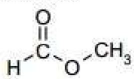
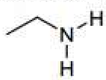
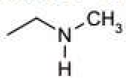
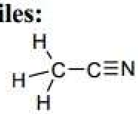
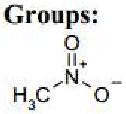
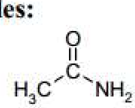
D) HANNA turbidimeter (HI98703)

E) Hot Air Oven

F) pH meter model (HANNA HI5521)

Appendix C: Principal IR Absorptions for Certain Functional Groups

Functional Group Names & **Example compounds**	**Absorption Ranges(cm^{-1})** [Look for a single absorption in these regions, unless stated otherwise.]	**Type of Vibration** causing IR absorption
Alkanes:  Methane	**3000-2800** (Note: The absorptions can be seen as several distinct peaks in this region.)	H-C-H Asymmetric & Symmetric Stretch
	1500-1440	H-C-H Bend
Alkenes:  1-Propene	**3100-3000**	C=C-H Asymmetric Stretch
	1675-1600	C-C=C Symmetric Stretch
Alkynes: $HC\equiv C-CH_3$ Propyne	**3300-3200**	$\equiv C-H$ Stretch
	2200-2100	$C\equiv C$ Stretch
Aromatic Rings:  Benzene	**3100-3000**	C=C-H Asymmetric Stretch
	1600-1580	C-C=C Symmetric Stretch
	1500-1450	C-C=C Asymmetric Stretch
Phenols & Alcohols:  Phenol  Methanol (Alcohol)	**3600-3100** (Note: Phenols MUST have Aromatic Ring Absorptions too.)	Hydrogen-bonded O-H Stretch (This peak usually appears much broader than the other IR absorptions.
Carboxylic Acids:  Formic Acid	**3400-2400** *(This peak always covers the entire region with a **VERY BROAD** peak.)*	Hydrogen-bonded O-H Stretch *[Note: This peak can obscure other peaks in this region.]*
	1730-1650	C=O Stretch

Ketones:  Acetone	**1750-1625**	C=O Stretch
Aldehydes:  Ethanal	**1750-1625**	C=O Stretch
	2850-2800	C-H Stretch off C=O
	2750-2700	C-H Stretch off C=O
Esters:  Methyl Formate	**1755-1650**	C=O Stretch
	(1300-1000)	(C-O Stretch)
Ethers:  Diethyl Ether (aka-Ethyl Ether)	**(1300-1000)**	(C-O Stretch)
Amines—Primary:  Ethylamine	**3500-3100 (TWO PEAKS!)**	N-H Stretch
	1640-1560	N-H Bend
Amines—Secondary:  N-Methylethylamine	**3500-3100 (ONE PEAK!)**	N-H Stretch
	1550-1450	N-H Bend
Nitriles:  Methanenitrile	**2300-2200**	C≡N Stretch
Nitro Groups:  Nitromethane (Note: Both peaks are <200 cm-1 apart.)	**1600-1500**	N=O Stretch
	1400-1300	N=O Bend
Amides:  Methanamide	**3500-3100**	N-H Stretch (similar to amines)
	1670-1600	C=O Stretch
	1640-1550	N-H Bend

(Olivares-pérez,et.al,2012)

Appendix D

I) Control for entire estimation of Color removal, PAC and Polyacrylamide (As control flocculant)

Sample/Treatment	1	2	3	4	5	6
PAC (ppm)	100	150	200	250	300	350
De-colorant (ppm)	200	250	300	350	400	450
Variable						
Polyacrylamide (ml)	0.5	1	1.5	2	2.5	3
Parameters						
PH	7.32	7.38	7.46	7.53	7.56	7.61
Color (pt-co)	582	406	218	44	25	35
Turbidity (NTU)	87	52	26	4.91	3.02	2.84
TSS (mg/l)	102	85	16	9	4	2
COD (mg/l)	294	197	150	142	117	91
BOD (mg/l)	112	89.2	64	61.4	49.8	36.6
Alkalinity (mg/l)	210	200	180	150	150	140
F-(mg/l)	1.95	1.82	1.37	1.26	1.23	1.11
PO43-(mg/l)	23.2	18.6	8.23	0.4	0.3	0.1
TN (mg/l)	11.3	8.6	5.9	4.2	3.3	2.8
SO43-(mg/l)	280	260	260	240	214	180
Ca^{2+} (mg/l)	14	12	9.4	9.2	9	8.9
Mg^{2+} (mg/l)	13	10.8	10.3	10	9.6	9.2

II) *Flocculant dose at constant PAC and Decolorant*

Varying the flocculant dose while the pH=7 and mixing time=50 Min maintained constant at the optimum value which will be from second and third phase to determine the optimum dose. For all phases the optimum value was picking depending on the highest removal efficiency of Color (pt-co), Turbidity (NTU), TSS (mg/l), COD (mg/l), BOD (mg/l), Alkalinity (mg/l), F^-(mg/l), PO_4^{3-} (mg/l), TN (mg/l) SO_4^{3-}(mg/l), Ca^{2+} (mg/l), Mg^{2+} (mg/l), and pH.

Sample/Treatment	1	2	3	4	5	6
PAC (ppm)	250	250	250	250	250	250
Decolorant (ppm)	350	350	350	350	350	350
Variable	***Flocculant dose at constant PAC and Decolorant***					
Level	0.5	1	1.5	2	2.5	3

Parameters						
PH	7.09	7.12	7.14	7.15	7.17	7.19
Color (pt-co)	418	206	87	39	26	18
Turbidity (NTU)	57	22	8	3.6	2.2	1.84
TSS (mg/l)	64	21	4	2	1	1
COD (mg/l)	196	184	178	161	146	137
BOD (mg/l)	170	92	81	72	69.6	67.4
Alkalinity (mg/l)	220	200	170	170	150	150
F^- (mg/l)	1.85	1.52	1.39	1.24	1.21	1.2
PO_4^{3-}(mg/l)	25.8	10.9	4.4	1.6	0.6	0.2
TN (mg/l)	10.8	7.2	4.3	3.6	3.2	1.9
SO_4^{3-}(mg/l)	270	250	240	220	180	150
Ca^{2+} (mg/l)	15.7	14	13.2	11.6	9.2	8.1
Mg^{2+} (mg/l)	11.8	11.3	11.1	10.1	9.5	9.2

III) Flocculant by extraction

Flocculant dose varies while the mixing time will keep constant to determine the optimum flocculant dose. Here the experimental factor will be flocculant dose ranging between 0.5 to 3 ppm. The removal efficiency of flocculant dose will be determined based on removed amount of Color (pt-co), Turbidity (NTU), TSS (mg/l), COD (mg/l), BOD (mg/l), Alkalinity (mg/l), F-(mg/l), PO_4^{3-} (mg/l), TN (mg/l) SO_4^{3-}(mg/l), Ca^{2+} (mg/l), Mg^{2+} (mg/l), and pH.

Sample/Treatment	1	2	3	4	5	6
PAC (ppm)	100	150	200	250	300	350
De-colorant (ppm)	200	250	300	350	400	450
Variable	Flocculant by extraction					
Cactus (ml)	0.5	1	1.5	2	2.5	3
Parameters						
PH	7.39	7.43	7.49	7.52	7.53	7.59
Color (pt-co)	518	311	148	90	29	16
Turbidity (NTU)	74	49	17	2.93	2.19	2.13
TSS (mg/l)	98	64	18	7	0	0
COD (mg/l)	286	201	188	157	146	136
BOD (mg/l)	171	98	84.4	72.6	70	68.4
Alkalinity (mg/l)	220	200	180	170	160	150

F^-(mg/l)	1.87	1.53	1.41	1.26	1.22	1.21
PO_4^{3-}(mg/l)	26.4	11.2	4.5	1.8	0.9	0.2
TN (mg/l)	10.9	7.4	4.8	3.9	3.6	2.1
SO_4^{3-}(mg/l)	270	260	240	230	180	150
Ca^{2+} (mg/l)	16	14.1	13.5	12	9.8	8
Mg^{2+} (mg/l)	12	11.8	11.2	10.6	9.9	9.6

IV) Determination of optimum mixing time

Investigate Optimum mixing time by providing optimum dose determined from the first phase. In this case the experimental factor will be mixing time which ranges from 5-30 minutes and then evaluate based on the removal efficiency of Color (pt-co), Turbidity (NTU), TSS (mg/l), COD (mg/l), BOD(mg/l), Alkalinity (mg/l), F^-(mg/l), PO_4^{3-} (mg/l), TN(mg/l) SO_4^{3-}(mg/l) , Ca^{2+} (mg/l), Mg^{2+} (mg/l), and pH.

Sample/ Treatment	1	2	3	4	5	6
PAC (ppm)	200	200	200	200	200	200
De-colorant (ppm)	300	300	300	300	300	300
Cactus (ml)	2	2	2	2	2	2
Variable	**mixing time**					
Level	10	20	30	40	50	60
Parameters						
PH	7.46	7.48	7.47	7.46	7.46	7.48
Color (pt-co)	139	136	128	123	120	126
Turbidity (NTU)	10	9.4	9	9	8	8.5
TSS (mg/l)	16	14	12	11	11	12
COD (mg/l)	184	182	182	180	181	180
BOD (mg/l)	83.5	83	83	82.1	81.8	82
Alkalinity (mg/l)	180	180	180	180	180	180
F^-(mg/l)	1.42	1.41	1.41	1.38	1.38	1.4
PO_4^{3-}(mg/l)	4.6	4.5	4.4	4.3	4.2	4.3
TN (mg/l)	4.9	4.8	4.8	4.5	4.4	4.7
SO_4^{3-}(mg/l)	250	240	240	230	230	220
Ca^{2+} (mg/l)	13.8	13.2	13	12.5	12.5	12.2
Mg^{2+} (mg/l)	11.7	11.6	11.5	11.5	11.3	11.2

V) Determination of optimum pH

Using the optimum dose and mixing time taken from the previous to determine the optimum pH. Here the only experimental factor will be pH where ranges from 4-10 and then evaluate based on the removal efficiency of Color (pt-co), Turbidity (NTU), TSS (mg/l), COD(mg/l), BOD(mg/l), Alkalinity (mg/l), F^-(mg/l), PO_4^{3-} (mg/l), TN(mg/l) SO_4^{3-}(mg/l), Ca^{2+} (mg/l), Mg^{2+} (mg/l), and pH.

Sample	1	2	3	4	5	6
PAC (ppm)	200	200	200	200	200	200
De-colorant (ppm)	300	300	300	300	300	300
Cactus (ml)	2	2	2	2	2	2
Variable	**PH**					
Level	4	6	7	8	9	10
Parameters						
PH	4.58	6.17	7.08	8.33	9.42	9.94
Color (pt-co)	159	142	132	185	377	396
Turbidity (NTU)	11	9.6	7.2	12	16	19
TDS (mg/l)	1747	1511	1368	1450	1568	1610
TSS (mg/l)	22	18	13	19	31	34
COD (mg/l)	198	192	180	183	185	189
BOD (mg/l)	93.6	90	84	86	87.1	87.5
Alkalinity (mg/l)	200	190	180	180	190	190
F^-(mg/l)	1.56	1.5	1.43	1.47	1.48	1.48
PO_4^{3-}(mg/l)	4.9	4.6	4.4	4.5	4.6	4.8
TN (mg/l)	5.1	4.7	4.6	4.8	4.8	4.9
SO_4^{3-}(mg/l)	4.58	6.17	7.08	8.33	9.42	9.94
Ca^{2+} (mg/l)	159	142	132	185	377	396
Mg^{2+} (mg/l)	11	9.6	7.2	12	16	19

VI) Determination of Optimum Dose at Optimum pH and Mixing Time

Varying the flocculant dose while the pH=7 and mixing time=50 Min maintained constant at the optimum value which will be from second and third phase to determine the optimum dose. For all phases the optimum value was picking depending on the highest removal efficiency of Color (pt-co), Turbidity (NTU), TSS (mg/l), COD (mg/l), BOD(mg/l), Alkalinity (mg/l), F^-(mg/l), PO_4^{3-} (mg/l), TN(mg/l) SO_4^{3-}(mg/l) , Ca^{2+} (mg/l), Mg^{2+} (mg/l), and pH.

Sample	1	2	3	4	5	6
PAC (ppm)	100	150	200	250	300	350
De-colorant (ppm)	200	250	300	350	400	450
Variable	**Optimum Dose at Optimum pH and Mixing Time**					
Cactus (ml)	0.5	1	1.5	2	2.5	3
Parameters						

PH	7.09	7.12	7.14	7.15	7.17	7.19
Color (pt-co)	460	227	116	84	24	16
Turbidity (NTU)	72	43	10	3.4	2.06	1.29
TDS (mg/l)	1244	1246	1251	1259	1309	1316
TSS (mg/l)	95	63	16	4	0	0
COD (mg/l)	282	194	181	149	132	127
BOD (mg/l)	170	92	81	72	69.6	67.4
Alkalinity (mg/l)	220	200	170	170	150	150
F^-(mg/l)	1.85	1.52	1.39	1.24	1.21	1.2
PO_4^{3-}(mg/l)	25.8	10.9	4.4	1.6	0.6	0.2
TN (mg/l)	10.8	7.2	4.3	3.6	3.2	1.9
SO_4^{3-}(mg/l)	270	250	240	220	180	150
Ca^{2+} (mg/l)	15.7	14	13.2	11.6	9.2	8.1
Mg^{2+} (mg/l)	11.8	11.3	11.1	10.1	9.5	9.2

VII) Determination of optimum Dose without Adding PAC

Sample	1	2	3	4	5	6
De-colorant (ppm)	200	250	300	350	400	450
Variable	Optimum Dose without Adding PAC					
Cactus (ml)	0.5	1	1.5	2	2.5	3
Parameters						
PH	7.28	7.3	7.33	7.35	7.37	7.39
Color (pt-co)	973	934	876	848	802	779
Turbidity (NTU)	74	68	63.7	60	57	53
TSS (mg/l)	152	141	123	118	110	102

VIII) Determination of optimum Dose without Adding PAC and De-colorant

Treatment	1	2	3	4	5	6
Variable	Optimum Dose without Adding PAC and De-colorant					
Cactus (ml)	0.5	1	1.5	2	2.5	3
Parameters						
PH	7.18	7.2	7.24	7.35	7.41	7.46
Color (pt-co)	1498	1333	1161	1132	1119	1112

Turbidity (NTU)	78	58	51.6	46	44.2	38
TSS (mg/l)	234	193	144	126	115	110
COD (mg/L)	512	473	364	318	305	294

IX) Cactus as Powder form (Without extraction)

Flocculant dose varies while the mixing time will keep constant to determine the optimum flocculant dose. Here the experimental factor will be flocculant dose ranging between 2-18g. The removal efficiency of flocculant dose will be determined based on removed amount of Color (pt-co), Turbidity (NTU), TSS (mg/l), COD (mg/l), BOD (mg/l), Alkalinity (mg/l), F-(mg/l), PO_4^{3-} (mg/l), TN (mg/l) SO_4^{3-}(mg/l), Ca^{2+} (mg/l), Mg^{2+} (mg/l), and pH.

Sample/treatment	1	2	3	4	5	6
PAC (ppm)	100	150	200	250	300	350
De-colorant (ppm)	200	250	300	350	400	450
Variable	**Flocculant as powder form (Without extraction)**					
Cactus (g)	2	4	8	12	16	18
Parameters						
PH	7.65	7.67	7.73	7.78	7.86	7.92
Color (pt-co)	701	652	618	540	503	481
Turbidity (NTU)	53	51	50	48	44	37
TSS (mg/l)	76	71	66	61	58	54
COD (mg/l)	484	353	280	245	197	169
BOD (mg/l)	216	172	136	122	89	67
Alkalinity (mg/l)	280	270	250	220	200	190
F^-(mg/l)	1.88	1.75	1.43	1.41	1.37	1.26
PO_4^{3-}(mg/l)	34.1	29.6	18.2	13.9	10.5	9.2
TN (mg/l)	18.4	10.2	8.9	6.3	5.8	3.6
SO_4^{3-}(mg/l)	300	270	250	220	200	190
Ca^{2+} (mg/l)	18	16	14.7	13	11.4	10.2
Mg^{2+} (mg/l)	14	11.7	10.5	9.9	9.7	9.4