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A Review on "Waste Water Treatment in Textile Industries Using Biocoagulant as Cactus Mucilage"

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Abstract

The issue of water contamination has gotten worse worldwide due to industrialization and population increase. The wastewater discharge techniques used by Ethiopia's textile sector do not comply with the national discharge standard. Because the discharge of inadequately treated or untreated textile effluent into the environment is becoming more frequent. Thus, minimizing this trend's harm to the environment requires using the best wastewater treatment technology. Coagulation is considered one of the most effective methods for treating textile wastewaters, which technically need to have a natural or artificial coagulant added to eliminate dangerous pollutants. Nonetheless, criticism has been leveled against the use of chemical coagulants due to their serious disadvantages. Nowadays Cactus mucilage introduced a new advancement by replacing synthetic coagulants, it's because of its properties to bind the suspended solids, days present in wastewater. Cactus mucilage contains polysaccharides and mucilage which helps in binding the suspended solids present in wastewater and making fit it for reuse. Cactus mucilage is a natural coagulant which is sustainable to the environment. During disposable of wastewater, synthetic coagulant can also degrade the soil hence Cactus mucilage also plays an important role in maintaining the soil properties. Cactus mucilage is an alternative to synthetic coagulants, it can be added with synthetic coagulants or it can be used alone. Cactus mucilage also helps us to reduce turbidity in wastewater. Nowadays it's generally used in industries because of low cost , easily available and easy to Performance of cactus mucilage is also superior when it's compared with synthetic coagulants. The ideal parameters were pH 4, 5 g/l of coagulant, 40 min of mixing time, 2 min of fast mixing at 100 rpm, 40 min of gradual mixing at 40 rpm, and 30 min of settling time. Under these ideal circumstances, 82.33 Moreover, cactus pad powder reduced turbidity by 53.16 %, TDS by 97 %, BOD by 58.75 %, COD by 25.37 %, Conductivity by 60 %, and TSS by 56.33 %. Therefore, using Cactus pad as a natural coagulant is advised. Rather than using Moringa seed, it efficiently eliminates turbidity, TDS, and TSS from wastewater effluents from the textile sector. Eventually, one of the natural coagulants employed in the coagulation process, Cactus pad, proved to be useful and was chosen.

Keywords: Cactus mucilage, Eco-friendly coagulant, Natural coagulant, Waste water treatment, Biodegradable coagulant, Sustainable coagulant, Pollutant removal, Dye extraction

1. Introduction:

Coagulation in wastewater treatment involves removal of suspended solids, organic compounds, and other harmful pollutants by destabilizing particles and making a floc that can be easily removed.Synthetic coagulants such as aluminum sulfate and ferric chloride have been widely used for this purpose. However, the use of chemical coagulant leds to damage to the sustainable environment. Cactus mucilage as a natural coagulant is safe for use and environment friendly. Cactus based coagulant has shown a superior performance as compared to synthetic coagulant. Furthermore, Cactus mucilage is a renewable and biodegradable coagulant hence reduces the burden on the environment.

Nowadays global water quality water standards becomes stricter which leds to increase in the use of natural coagulants. Cactus mucilage contains polysaccharides gel which has a property to bind the suspended solids to make the floc. The cactus mucilage contains sugars, pectin, and proteins, which interact with pollutants in the water to form larger floc that can be removed by sedimentation or filtration. Cactus mucilage has also a property of removing turbidity from the waste water. Due to locally availability of cactus, the use of Cactus mucilage has been exploring widely. Studies shows cactus mucilage can be also beneficial in removing metals present in the waste water. As compared to synthetic coagulants, cactus mucilage is non- toxic, biodegradable, and cost-effective. Cactus-based coagulants do not introduce residues into the treated water, hence reduces the impact on human health.

According to Rojas, M. S., there is an abundance of dangerous contaminants in textile effluent, both in terms of volume and substance. This is troubling because it is estimated that the industry will require 200 L of water to create 1 kg of textiles. However, textile effluents that contain non-biodegradable components, are salinized, or have brilliant colors may have a high biological and chemical oxygen demand. It also includes trace levels of metals like copper, zinc, arsenic, and chrome along with oils, greases, and waxes. One efficient method for treating textile wastewater is coagulation. This method has been verified to eliminate organic materials that raise the BOD and COD contents of wastewater, as well as dissolved, suspended, and colored dyes that cause turbidity. To solve the issues with chemical coagulants, more natural coagulants must be used in the treatment of drinking water. Generally speaking, naturally occurring coagulants are thought to be harmless for human health. Numerous natural coagulants were created or isolated from microbes, animals, or plants as a result of some research that was done on the subject. Moringa seeds are among the substitutes. An excellent illustration of a so-called "multipurpose tree" is the Moringa. According to earlier research, Moringa is non-toxic and should be used as a coagulant in impoverished nations.

The ideal parameters were pH 4, 5 g/l of coagulant, 40 min of mixing time, 2 min of fast mixing at 100 rpm, 40 min of gradual mixing at 40 rpm, and 30 min of settling time. Under these ideal circumstances, 82.33 Moreover, cactus pad powder reduced turbidity by 53.16 %, TDS by 97 %, BOD by 58.75 %, COD by 25.37 %, Conductivity by 60 %, and TSS by 56.33 %.

Therefore, using Cactus pad as a natural coagulant is advised. Rather than using Moringa seed, it efficiently eliminates turbidity, TDS, and TSS from wastewater effluents from the textile sector. Eventually, one of the natural coagulants employed in the coagulation process, Cactus pad, proved to be useful and was chosen.

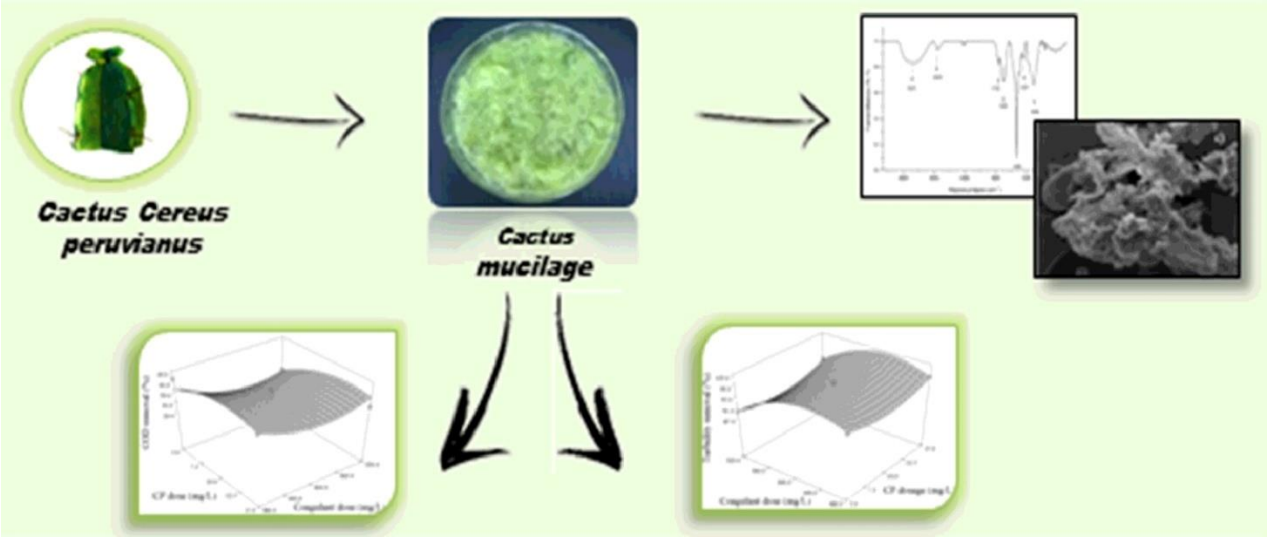

Fig of textile effluent treatment using cactus

2.1 Methodology:

Cactus Mucilage Extraction: Mucilage was extracted from Opuntia ficus-indica pads. The pads were cleaned, peeled, and mucilage was manually scraped from the inner tissues. The mucilage was filtered to remove any particulate matter and diluted to various concentrations (0.5 g/L to 2.0 g/L) for the coagulation process.

Wastewater Sample Collection: Wastewater from the textile dyeing unit was collected, which typically contained high turbidity (200 NTU), high COD (Chemical Oxygen Demand), and dye concentrations. The main contaminants included reactive dyes (such as azo and anthraquinone-based dyes), along with heavy metals such as cadmium (Cd), lead (Pb), and chromium (Cr). Coagulation and Flocculation:

The coagulation experiments were carried out by adding different concentrations of cactus mucilage to the wastewater samples.

After agitating the mixture for 30 minutes, flocculation was allowed to occur, followed by a 1-hour sedimentation period. For comparative analysis, alum was used as a conventional coagulant at standard dosages.

pH and Temperature Control: The experiments were conducted at an optimal pH range of 6–7, and the temperature was maintained at 25°C to simulate typical conditions in wastewater treatment.

2.2 Concentration of Cactus Mucilage Alone:

Cactus mucilage is known for its ability to remove suspended solids, turbidity, and some organic contaminants in wastewater. The optimal concentration of cactus mucilage varies based on the specific characteristics of the wastewater, such as the level of turbidity, pH, and the type of pollutants present.

Typical Concentrations for Cactus Mucilage:

For effective coagulation, cactus mucilage concentrations typically range from 0.5 g/L to 2.0 g/L in wastewater. The optimal concentration is usually determined based on trial-and-error experiments, taking into account the wastewater's properties.
At lower concentrations (0.5 g/L to 1.0 g/L), cactus mucilage is effective in reducing turbidity and suspended solids in textile wastewater, though the removal of heavy metals may not be as high.
At higher concentrations (1.5 g/L to 2.0 g/L), cactus mucilage can achieve higher removal rates of turbidity, suspended solids, and some heavy metals, but care must be taken to avoid over-dosage, which can lead to negative effects such as increased sludge generation.

2.3 Combination of Cactus Mucilage and Synthetic Coagulants:
Combining cactus mucilage with synthetic coagulants such as alum (Aluminum sulfate) or ferric chloride has been shown to enhance the coagulation process, particularly in the removal of heavy metals and dyes, while still providing the benefits of using a natural coagulant.

- **Alum + Cactus Mucilage:**

Concentrations: The combination of cactus mucilage with alum is often tested at concentrations of 0.5 g/L to 1.0 g/L for cactus mucilage and 10 mg/L to 50 mg/L for alum.

Effectiveness: This combination removes about 80-90% turbidity and about 75% dye removal.

Ferric Chloride + Cactus Mucilage:

Concentrations: The recommended concentration of ferric chloride ranges from 10 mg/L to 30 mg/L, while cactus mucilage is used at concentrations of 0.5 g/L to
1.5 g/L.

Effectiveness: This combination removes about 70-75% dye removal and 75-80% heavy metals.

Chemicals and reagents

Many chemicals were used in the experiment, one of which being distilled water, which was used to clean the raw materials and make reagents for turbidity testing. To maintain good hygiene, detergent was used to clean hands. The main raw materials used in the studies were cactus pads and Moringa seeds. In addition, the pH of the sample water was adjusted using a buffer solution with a pH of 4.7. Oil was extracted from the powdered Moringa seeds using hexane. The chemical engineering department at Wollo University has easy access to all of these compounds in its chemistry laboratory.

Methods coagulant preparation
The thorns and outer covering of the cacti were removed, and the samples were put in fresh, clean polyethylene plastic bags after being thoroughly cleaned in distilled water. The interior of the plant, or cactus mucilage, was gathered and dried in an oven set to a temperature of 65 ◦C. The composition of the mucilage may become denatured if the temperature rises over this point. After that, the dry material was stored for a whole day. A coffee mill was then used to grind the dried cactus material into a powder,

and any particles smaller than 400 µm were removed by sieving. After being used for coagulation, this powder was stored at room temperature until the analysis. For this investigation, Moringa seed was manufactured concurrently.

Considering that the Moringa seed can be used as a coagulant in two different ways: by using it as a regular seed or by extracting its oil (defatted cake). Some research have suggested that using defatted Moringa seed is important to improve the effectiveness of wastewater treatment.

According to this advice, defatted Moringa seed was made as follows: The seeds with pods on them were first manually separated. Since green seeds have little coagulation activity, the seeds with outer shells are dried in the sun. After being dried, seeds are then manually removed from their outer shells. Following the drying of the seed kernel, the material was ground into a fine powder, about 400 µm in size, using a domestic mill to achieve the solubilization of the seed's active components. The powder was then allowed to soak in hexane for 30 min at room temperature, stirring now and then. 500 ml of hexane was mixed with 100 g of the powder. To obtain the defatted cake, the solution must be filtered via filter paper. The residual solids (process cake) are dissolved in water, stirred, and filtered before being dried for 24 h at 40 ◦C in an oven.

This is useful in getting rid of any hexane that might be present in the powdered seed cake. Ultimately, the powdered dry seed was kept at room temperature until it was needed for coagulation. Generally, the flow diagrams of Moringa seed powder in defatted cake form preparation.
Plant-based polymeric coagulants can be used in the CF process because they are highly biodegradable, cost-effective, non-toxic, and generally have a large number of surface charges and adsorption sites that can increase the efficiency of the coagulation process. *Aloe vera* (*Aloe barbadensis Miller*) has natural polysaccharides with oxygen-containing functional groups throughout their molecular structures (e.g. carboxyl and hydroxyl groups), which can interact with contaminants, [19]. Studies involving CF activity using natural coagulants, such as *Linum usitatissimum* L., *Enteromorpha*, *Moringa oleifera* seed [16], chitosan [30], *Cucurbita pepo L.* [31], *Abelmoschus esculentus* , and nirmali seeds , have been reported previously.

RESULTS AND DISCUSSIONS

Cactus Mucilage Concentration	Dye extraction	Effectiveness	Notes
1% (w/v)	Moderate coagulation	Effective for low turbidity water, reducing turbidity by (50-60)%	Effective for low-to- medium concentration dyes.
2% (w/v)	Good coagulation	Moderate reduction in turbidity (60-70)%	Commonly used for many dye types; balances effectiveness and cost.
3% (w/v)	Strong coagulation	Significant turbidity reduction (70-80)%	Recommended for more difficult dyes or larger quantities.
5% (w/v)	Very strong coagulation	High turbidity reduction (80-90)%	Suitable for very high-turbidity or strong-colored dyes.
Above 5% (w/v)	Maximum coagulation	Can lead to excessive flocculation or over-coagulant	Used for maximum extraction efficiency, but may be wasteful for certain applications.

2.3.1 : Cactus mucilage used with synthetic coagulants:

Coagulant Combination	Cactus Mucilage Concentration (g/L)	Synthetic Coagulant Concentration	Target Pollutant	Removal Efficiency
Cactus Mucilage+Alum	0.5 g/L to 1.0 g/L	Alum:10mg/L to 50mg/L	Turbidity, Suspended Solids, Dyes, Heavy Metals	80-90% Turbidity Removal 70-75% Dye Removal

Cactus Mucilage+Alum	1.0g/L to 1.5 g/L	Alum:20mg/L to 40mg/L	Dyes, Suspended Solids, COD, Dyes, Heavy Metals	75-80% Turbidity Removal 70-80% Heavy Metal Removal
Cactus Mucilage+Ferric Chloride	0.5 g/L to 1.0 g/L	Ferric Chloride:10mg/L to 30mg/L	Suspended Solids, Dyes, COD, Heavy Metals	65-70% COD Removal 75-80% Heavy Metal Removal
Cactus Mucilage+Ferric Chloride	1.0 g/L to 1.5 g/L	Ferric Chloride:10mg/L to 50mg/L	Suspended Solids,COD, Dyes, Heavy Metals	70-75% Dye Removal 75-80% Heavy Metal Removal
Cactus Mucilage Alone	0.5 g/L to 2.0 g/L	None	Turbidity, Suspended Solids, Dyes, Heavy Metals	75-85% Turbidity Removal 60-70% Dye Removal

The case study results demonstrate that cactus mucilage is a promising alternative to conventional synthetic coagulants for textile wastewater treatment. While cactus mucilage performed slightly less efficiently than alum in removing heavy metals and dyes, it showed comparable performance to alum in terms of turbidity and suspended solids reduction. The primary benefits of cactus mucilage lie in its biodegradable nature, cost-effectiveness, and non-toxic characteristics, making it an environmentally sustainable choice for wastewater treatment in industries such as textiles.

Moreover, the use of cactus mucilage can reduce the environmental burden associated with the disposal of toxic chemical coagulants. This makes it a suitable option for industries aiming to adopt more sustainable practices. Further research into optimizing the coagulation process, particularly to improve heavy metal and dye removal efficiency, will further enhance the performance of cactus mucilage as a coagulant.

3.1 Coagulation Process and Optimization

Flocculation Efficiency: The combination of cactus mucilage with synthetic coagulants enhances the formation and settling of flocs, which is vital for removing suspended solids and improving water clarity. Cactus mucilage aids in increasing the size and density of the flocs, facilitating faster sedimentation. This results in a more efficient separation of solids from the treated water.

Pollutant Removal: The combination of cactus mucilage with synthetic coagulants like alum or ferric chloride has been shown to significantly improve the removal of dyes, suspended solids, and heavy metals. While alum is effective in removing turbidity and suspended solids, cactus mucilage aids in dye removal and enhances the overall flocculation process, resulting in better pollutant removal (Tahir et al., 2019 (45); Singh & Chhabra, 2017 (46).

Cost-Effectiveness: Cactus mucilage, being a low-cost natural coagulant, can help reduce the amount of synthetic coagulants required for effective treatment. When combined with alum or ferric chloride, cactus mucilage reduces the overall cost of treatment while maintaining effective pollutant removal. This makes it an economical and sustainable alternative for wastewater treatment in industries (Singh et al., 2020 (47); Ramírez et al., 2016 (48).

3.2 Experimental Findings from Case Studies

In a study conducted at a textile dyeing facility, concentrations of cactus mucilage ranging from 0.5-1g/L added with 10-50mg/L of alum, results 80-90% turbidity removal and70-75%.

4. Conclusion

The combination of cactus mucilage and synthetic coagulants like alum or ferric chloride presents an effective, sustainable solution for wastewater treatment in textile industries. The optimal concentration of cactus mucilage typically ranges from 0.5 g/L to 1.0 g/L, while alum or ferric chloride is used at concentrations of 10 mg/L to 50 mg/L. This combination enhances coagulation and flocculation processes, leading to improved removal of suspended solids, dyes, and heavy metals. Additionally, using cactus mucilage can reduce the reliance on synthetic coagulants, thus offering a cost-effective and environmentally friendly solution for industrial wastewater treatment.

The necessity of treating textile wastewater was thrown into sharp relief by this investigation. Coagulation, the method used in the study, was demonstrably effective at removing nasty stuff from wastewater. It had an initial turbidity of 235 NTU (nephelometric turbidity units), a pH of 8.5, and a total solid content (TS) of 6000 mg/L. Of that, 3500 mg/L was dissolved solids (TDS), and 1750 mg/ L was suspended solids (TSS). Several tasks were carried out to fulfill the aim of the study. The natural coagulants powdered Moringa seeds and cactus pads were tested and found to be extremely effective. They reduced the turbidity, total dissolved solids, and total suspended solids to the point where these could be classified as clean and safe to discharge. The data shows that cactus seed treatment is more effective than Moringa seed treatment for purifying water across all the measured criteria.

Following treatment with the seeds of the cactus, the water had a turbidity of 110 NTU, total dissolved solids (TDS) of 120 mg/L, biochemical oxygen demand (BOD) of 198 mg/L, chemical oxygen demand (COD) of 1000 mg/L, and conductivity of 2000 µS/cm. In contrast, after treatment with Moringa seeds, the same water had turbidity of 160 NTU, TDS of 910 mg/L, BOD of 201 mg/L, COD of 1005 mg/L, and conductivity of 2012 µS/ cm. Taken together, these variables indicate that the cactus seeds are a superior coagulant. Natural coagulants certainly provide an excellent treatment of industrial wastewater, yielding a very high treatment efficiency. This study shows that they are also quite suitable for developing countries: they are inexpensive most are free, in fact so direct costs are low; and they are sustainable because they are made from renewable resources. Using natural coagulants thus addresses the challenge of environmental sustainability in two ways: first, because they themselves are environmentally friendly; and second, because their low cost greatly lessens the chance that wastewater treatment will be abandoned, which could happen if direct treatment costs are too high.

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