Analysis on Sustainable Solutions For Tannery Effluent Treatment Using Plant-Based Coagulants

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Abstract- *Tannery industries release substantial quantities of effluent with high amounts of organic matter, heavy metals, and suspended particles, resulting in significant environmental damage. Ranipet, Tamil Nadu, is a significant leather processing hub where untreated effluents have prompted significant concerns. Traditional chemical coagulants, such alum and ferric chloride, while effective, lead to secondary pollution and sludge disposal challenges. This research examines the efficacy of Moringa oleifera seed extract and Tamarindus indica seed powder as natural coagulants for the treatment of tannery effluent. Wastewater samples obtained from tannery units underwent jar tests to assess critical parameters, such as turbidity, chemical oxygen demand (COD), total suspended solids (TSS), and pH. The results indicated that Moringa oleifera was particularly successful in removing turbidity due to its ionic proteins, but Tamarindus indica seed powder exhibited significant chemical oxygen demand (COD) reduction, reflecting superior organic pollutant adsorption capabilities. Both coagulants yielded good outcomes within an optimal dosage range, providing them viable alternatives to manufactured chemicals. This research emphasizes the efficacy of natural coagulants in sustainable wastewater treatment, presenting an environmentally benign and economical strategy for industrial effluent control. Additional study is advised for extensive application and sludge characterisation.*

Keywords- Tannery wastewater, natural coagulants, Moringa oleifera, Tamarindus indica, turbidity removal, chemical oxygen demand, sustainable wastewater treatment, eco-friendly coagulants.

I. INTRODUCTION

Tannery industries generate significant amounts of wastewater with high quantities of organic matter, heavy metals, and suspended particulates. When these pollutants are discharged without sufficient treatment, they cause serious environmental and health issues (Chiampoet al., 2023; Kato &Kansha, et al., 2024). The leather business in Ranipet, Tamil Nadu, contributes significantly to the local economy while also causing serious water pollution.

A. Tannery Wastewater Characteristics

Tannery wastewater is recognized for having high levels of organic matter, chromium, sulfides, and suspended particles, making it one of the most difficult industrial effluents to treat (Zhao et al., 2022). Untreated tannery effluents have been shown in studies to contaminate groundwater, disrupt aquatic habitats, and pose health concerns to adjacent communities (Prakash et al., 2021; Bhardwaj et al., 2023). Effective treatment strategies are required to reduce these effects and ensure compliance with environmental discharge laws (Bikrametal.,2023).

B.Traditional Coagulants in Wastewater Treatment

Chemical coagulants like alum, ferric chloride, and polyaluminum chloride (PAC) are commonly employed in wastewater treatment. They effectively remove turbidity and impurities, but they are expensive, cause secondary pollution, and produce a lot of sludge (Kato & Kansha, et al., 2024; Bhupendra et al., 2022). Recent research indicates that chemical coagulants may introduce residual aluminum, which has been associated to neurotoxicity and environmental hazards (Mortula et al., 2009). This has prompted researchers to investigate alternatives, such as plant-based coagulants.

C. Natural coagulants in wastewater treatment

Natural coagulants derived from plants have gained popularity due to their biodegradability, non-toxicity, and long-term benefits (Vicky et al., 2017; Mutegoa, 2024). Moringa oleifera and Tamarindus indica are two plant-based coagulants that have showed promise in cleaning industrial effluents. Moringa oleifera seeds contain cationic proteins that neutralize negatively charged particles in wastewater, resulting in turbidity and suspended solids removal (Pundir et al, 2024;Pareek et al., 2023). Nargis & Koul (2020) found that Moringa oleifera seed extract reduced turbidity by more than 80% in tannery wastewater treatment. Similarly, Tamarindus indica seed powder has been shown to efficiently lower COD and TSS due to its high polysaccharide and fiber content (Mortula, et al 2009; Zaman et al., 2021). These natural

coagulants are an environmentally benign and cost-effective alternative to chemical treatments that can be scaled up for larger-scale applications (Gautam, & Saini, 2020).

D. Research Gaps and Objectives

While various studies have looked at the use of natural coagulants in wastewater treatment, nothing is known about their combined effectiveness in treating tannery effluents (Singh et al., 2022). The intention of this study is to determine the coagulation efficiency of Moringa oleifera and Tamarindus indica in lowering turbidity and COD in tannery effluent. The findings will help to improve sustainable wastewater management techniques in the leather sector and offer an environmentally acceptable alternative to chemical coagulants (Bhardwaj, et al., 2023).

II. MATERIALS AND METHODOLOGY

A.Materials

The tannery effluent collected from a tannery industry in Ranipet, Tamil Nadu, India, is utilized in the study. The effluent is transported to the laboratory for analysis in plastic containers. The treatment procedure employs two natural coagulants: Moringa oleifera seed powder and Tamarind seed powder. Analytical grade reagents were employed throughout the investigation.

III. METHODOLOGY

A. Sample Collection and Characterization

Tannery effluent is collected from the discharge locations of a tannery unit in Ranipet. The samples are conveyed to the laboratory under controlled conditions and stored in airtight plastic containers.

Prior to treatment, the effluent undergoes an analysis for critical water quality parameters, including pH, turbidity, TDS, COD, and BOD. The pertinent Indian Standards codes that are relevant to this investigation are summarized in Table 1.

Table 1. Indian Standards (IS) codes relevant to water and wastewater analysis

Parameter	IS Code
pH	IS 3025 (Part 11): 1983
Turbidity	IS 3025 (Part 10): 1984
TDS	IS 3025 (Part 16): 1984
COD	IS 3025 (Part 58): 2006
BOD	IS 3025 (Part 44): 1993

B. Preparation of Natural Coagulants

Moringa oleifera seeds are obtained, dried in the shade, then dehulled. The dried seeds are pulverized into a fine powder with a mechanical grinder. Similarly, tamarind seeds are cleaned, dried, and ground into powder. Both powders are sieved through a 250-micron screen to ensure uniform particle size.

The powders are kept in sealed containers to avoid moisture absorption. Before being utilized in the treatment process, the powders are mixed with distilled water at various quantities to create coagulant solutions.

Fig.1 and Fig.2 demonstrates the fine powders obtained from Moringa oleifera seeds and tamarind seeds.

Fig 1. Moringa oleifera seed powder

Fig 2. Tamarind seed powder

C. Coagulation and Flocculation Process

The coagulation procedure is carried out using a standard jar test instrument. The technique includes the following steps; In separate beakers, 500 mL of tannery effluent is mixed with varying dosages of Moringa oleifera and Tamarind seed powders (0.5 g/L to 3.0 g/L). Samples are rapidly mixed at 150 rpm for 2 minutes to ensure consistent distribution of coagulants. Slowly mix at 50 rpm for 15 minutes to stimulate floc development. Allow the ingredients to settle for 30 minutes without stirring. Following the settling period, the supernatant is carefully collected and tested for water quality criteria to determine treatment efficiency.

Fig.3 demonstrates the standard jar test setup employed to ascertain the optimal coagulant dosage for the treatment of tannery effluent

Fig 3. Test setup for coagulation

IV. EXPERIMENTAL RESULTS

The efficacy of Moringa oleifera and tamarind seed powders as natural coagulants in treating tannery effluent was determined by comparing major water quality metrics before and after treatment.

The parameters evaluated were pH, turbidity, TDS, COD, and BOD.

A. Initial Characterization of Tannery Effluent

Prior to treatment, the tannery effluent had a yellowish-brown colour and an unpleasant stench, indicating significant levels of organic and inorganic compounds.

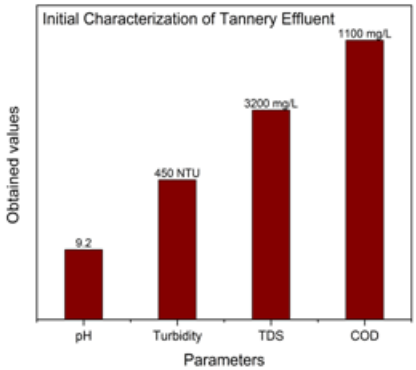


Fig.4 exhibits the initial characteristics of the tannery effluent.
Fig 4. Initial Characterization of Tannery Effluent

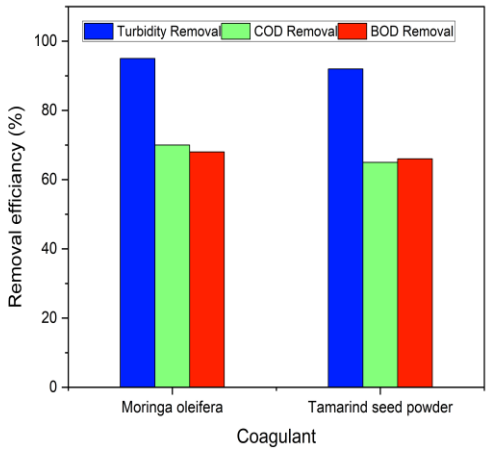
B. Optimization of Coagulant Dosage

A series of jar tests were undertaken to establish the best dosage for each coagulant at concentrations ranging from 0.5 g/L to 3.0 g/L. The optimum Moringa oleifera dosage was found to be 2.0 g/L, which resulted in considerable reductions in turbidity (95%), COD (70%), and BOD (68%). Similarly, tamarind seed powder performed best at a dosage of 1.5 g/L, with 92% turbidity removal, 65% COD reduction, and 66% BOD reduction. These findings highlight the efficacy of both natural coagulants in treating tannery effluent, providing a more sustainable and cost-effective alternative to traditional chemical coagulants.The appropriate dosages were determined by the best removal efficiency for turbidity, COD, and BOD. Table 2 and Fig. 4 illustrate the optimum doses and associated removal efficiencies of Moringa oleifera and tamarind seed powder as natural coagulants in the treatment of tannery effluent.

Table 2. Optimal Dosages and Corresponding Removal Efficiencies of Natural Coagulants

Coagulant	**Optimal Dosage**	**Turbidity Removal**	**COD Removal**	**BOD Removal**
Moringa oleifera	2.0 g/L	95%	70%	68%
Tamarind seed powder	1.5 g/L	92%	65%	66%

Fig.5 Removal efficiency of natural coagulants



C. Post-Treatment Analysis

The use of Moringa oleifera and tamarind seed powders greatly improved the quality of tannery effluent. Moringa oleifera was more effective at reducing turbidity, COD, and BOD than tamarind seed powder. The pH levels of the treated effluents were adjusted closer to neutral, making them suitable for disposal into aquatic bodies. These findings are consistent with earlier research demonstrating the efficacy of Moringa oleifera in wastewater treatment. For example, a study found that Moringa oleifera seed powder reduced turbidity by 98% and COD by 65.8% in acidic wastewater

conditions. Similarly, tamarind seed powder has been beneficial in treating industrial wastewater, with considerable reductions in turbidity and COD levels. Table 3 summarizes the outcomes of the post-treatment analysis.

Table 3. Test outcomes on Post-Treatment Analysis

Parameter	Untreated Effluent	Moringa oleifera Treated	Tamarind Seed Powder Treated
pH	9.2	7.8	8.0
Turbidity	450 NTU	22.5 NTU	36 NTU
TDS	3200 mg/L	2880 mg/L	2940 mg/L
COD	1100 mg/L	330 mg/L	385 mg/L
BOD	600 mg/L	192 mg/L	204 mg/L

V. CONCLUSION

This study investigated the efficacy of natural coagulants, Moringa oleifera seed powder and tamarind seed powder, in treating tannery effluent. The optimum dosage for Moringa oleifera was shown to be 2.0 g/L, resulting in considerable decreases in turbidity (95%), COD (70%), and BOD (68%). The best dosage of tamarind seed powder was 1.5 g/L, which resulted in 92% turbidity reduction, 65% COD reduction, and 66% BOD reduction. After treatment, the effluent's pH was adjusted closer to neutral, making it suitable for discharge into aquatic ecosystems. These data indicate that both natural coagulants are successful at improving tannery effluent quality, with Moringa oleifera having somewhat greater removal efficiency across the parameters tested. The use of these natural coagulants provides a sustainable and cost-effective alternative to conventional chemical coagulants, helping to safeguard the environment and comply with regulatory standards.

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