

# Sustainable treatment of laundry wastewater using *Moringa oleifera* seed extract as a natural biocoagulant: Performance and optimization

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## ABSTRACT

*This study evaluates the potential of Moringa oleifera seed extract as an eco-friendly biocoagulant for treating synthetic laundry wastewater. Laboratory-scale experiments were conducted using a jar test procedure, with doses of moringa seed extract ranging from 10 to 5 g/L. The coagulation efficiency was analyzed based on turbidity removal, chemical oxygen demand (COD) reduction, and total suspended solids (TSS) reduction, and the performance was compared to conventional coagulants, including alum and ferric chloride. Results indicate that the optimal dose of moringa seed extract was 4 g/L, achieving 52% turbidity removal, 35% COD reduction, and 75% TSS reduction. While the turbidity removal efficiency of moringa seed extract was lower than that of alum (92%) and ferric chloride (90%), its performance in TSS reduction was comparable. The findings suggest that moringa seed extract can serve as a sustainable alternative to chemical coagulants, particularly for TSS reduction, with the added benefits of biodegradability and low toxicity. However, its moderate efficacy in turbidity and COD removal indicates that it is best utilized as part of an integrated treatment process. The study highlights the potential of Moringa oleifera as a cost-effective and environmentally friendly solution for wastewater management, particularly in resource-limited settings.*

## 1. INTRODUCTION

Water pollution caused by untreated wastewater is a global issue that requires urgent attention. Among the various sources of water pollution, laundry wastewater poses a significant challenge due to its high turbidity, presence of surfactants, and other organic contaminants. Laundry effluents, particularly from small- and medium-scale laundry operations, are often discharged directly into water bodies without adequate treatment. This contributes to environmental degradation, affecting aquatic ecosystems and public health [1]. The pollutants in laundry wastewater are not only aesthetically

displeasing but also harmful, as they disrupt aquatic life and contaminate freshwater resources.

Conventional methods to address water pollution rely heavily on chemical coagulants [2]–[13], such as aluminum sulfate (alum) and ferric chloride. These substances effectively reduce turbidity and remove suspended solids by facilitating the coagulation and sedimentation process. However, their long-term application raises several concerns. Residual chemicals from these coagulants can lead to secondary pollution, affecting the quality of treated water. Additionally, the sludge generated during the process requires

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careful management to prevent further environmental harm. The increasing awareness of these challenges has motivated researchers to seek sustainable, eco-friendly alternatives that can achieve similar or better results with minimal environmental impact [14].

One promising solution lies in the use of natural coagulants derived from plants. Among these, *Moringa oleifera* has emerged as a highly effective and sustainable option. Commonly known as the drumstick tree, *Moringa oleifera* is native to South Asia but is now widely cultivated in many parts of the world due to its nutritional, medicinal, and environmental benefits. The seeds of this plant contain proteins with cationic properties, making them ideal for coagulation and flocculation processes. These properties enable moringa seeds to neutralize negatively charged particles in water, thereby reducing turbidity and facilitating sedimentation [15]. Furthermore, the use of moringa seeds as coagulants generates biodegradable sludge, which can be safely disposed of or repurposed for agricultural use.

Several studies have demonstrated the effectiveness of moringa seeds in treating various types of water, including river water, well water, and municipal wastewater. For example, Ndabigengesere and Narasiah (1998) reported that moringa seeds could remove over 90% of turbidity from water samples in laboratory conditions [16]. Similarly, other researchers have highlighted the seed's potential to reduce organic pollutants and improve water clarity. However, the application of moringa seeds as biocoagulants for treating laundry wastewater remains relatively underexplored. This is surprising, given that laundry wastewater contains pollutants, such as synthetic detergents and surfactants, which are likely to interact with the cationic proteins in moringa seeds.

This study aims to address this gap by investigating the potential of moringa seeds as an innovative biocoagulant for mitigating the turbidity of laundry wastewater. The research focuses on optimizing the use of moringa seed

extracts, evaluating their coagulation efficiency, and comparing their performance with conventional chemical coagulants.

## 2. MATERIALS AND METHOD

### 2.1. Materials

The primary material used in this study was *Moringa oleifera* seeds, sourced from a local supplier to ensure freshness and availability. The seeds were cleaned, sun-dried, and manually dehulled to extract the kernels. Analytical-grade chemicals, including aluminum sulfate (alum) and ferric chloride, were used as reference coagulants. Synthetic laundry wastewater was prepared to simulate typical effluent characteristics, comprising surfactants, detergents, and suspended solids. Distilled water was used throughout the experiments to minimize contamination. Equipment included a jar test apparatus, turbidity meter, pH meter, and a spectrophotometer for water quality analysis.

### 2.2. Methods

#### 2.2.1. Preparation of Moringa Seed Extract

The moringa seed kernels were ground into a fine powder using a laboratory grinder. To prepare the coagulant solution, 10 grams of moringa seed powder were dissolved in 1 liter of distilled water and stirred for 30 minutes. The suspension was filtered through muslin cloth to obtain the aqueous extract, which was stored at 4°C until use.

#### 2.2.2. Experimental Procedure

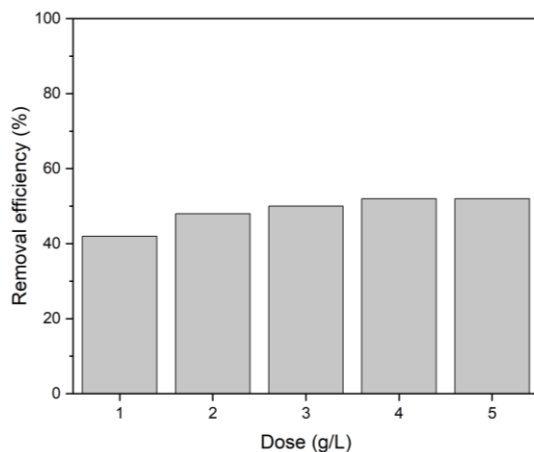
The coagulation and flocculation experiments were conducted using a standard jar test procedure. Synthetic laundry wastewater (1 liter) was placed in each jar of the test apparatus. Varying doses of moringa seed extract (11–5 g/L) were added to the wastewater samples, and the solution was stirred at 150 rpm for 30 minutes (rapid mixing) followed by 50 rpm for 30 minutes (slow mixing). Sedimentation was allowed for 30 minutes before sampling.

#### 2.2.3. Analysis of Water Quality

The treated water samples were analyzed for turbidity, chemical oxygen demand (COD), and total suspended solids (TSS). Turbidity was measured using a turbidity meter, while COD using permanganometry and TSS were determined following standard methods for water and wastewater analysis.

### 3. RESULT AND DISCUSSION

The results of this study demonstrate the potential of *Moringa oleifera* seed extract as a natural biocoagulant for treating synthetic laundry wastewater. The coagulation performance was evaluated across various doses, focusing on turbidity removal, chemical oxygen demand (COD) reduction, and total suspended solids (TSS) reduction. Comparisons were also made with conventional chemical coagulants, such as alum and ferric chloride.



**Figure 1.** Turbidity Removal

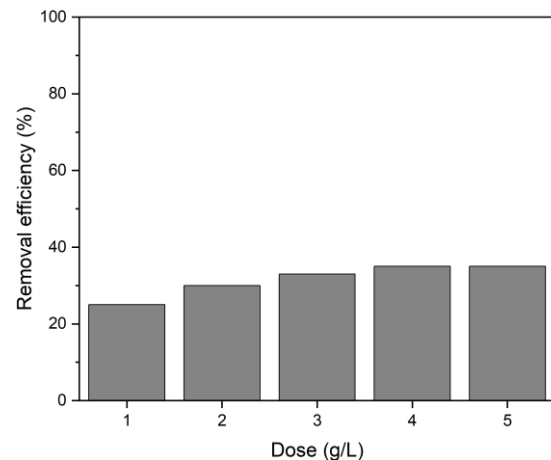
#### 3.1. Turbidity Removal

The turbidity removal efficiency of moringa seed extract increased with dosage, reaching a maximum of 52% at 4 g/L. However, further increases in the dose (5 g/L) did not result in improved turbidity removal, indicating that the optimal dose was 4 g/L (**Fig 1.**). This plateau effect may be attributed to the saturation of coagulation sites, beyond which additional coagulant does not contribute to further aggregation of particles. Similar findings were reported by Ndabigengesere and Narasiah (1998), who observed diminishing returns at higher doses of *Moringa oleifera* seed extract in water treatment [16]. The performance of

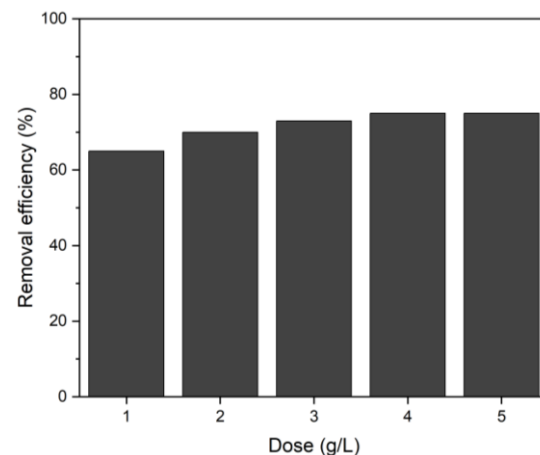
moringa seed extract was lower compared to alum (92%) and ferric chloride (90%), emphasizing the need for further refinement in preparation or application methods, as supported by Okuda et al. (2001) and Pritchard et al. (2010) [17], [18].

#### 3.2. COD Reduction

The COD reduction followed a similar trend, peaking at 35% at 4 g/L and showing no further improvement at 5 g/L (**Fig 2**). The moderate reduction in COD indicates that moringa seed extract primarily targets suspended solids rather than dissolved organic matter. Tong et al. (2022) found similar results, noting that natural coagulants are more effective for removing particulate matter than for dissolved contaminants [1]. Despite the modest COD reduction, the findings align with Ndabigengesere et al. (1995) and Goncalves et al. (2024), who highlighted the supplementary role of moringa seeds in wastewater treatment processes [16], [19].



**Figure 2.** COD Removal



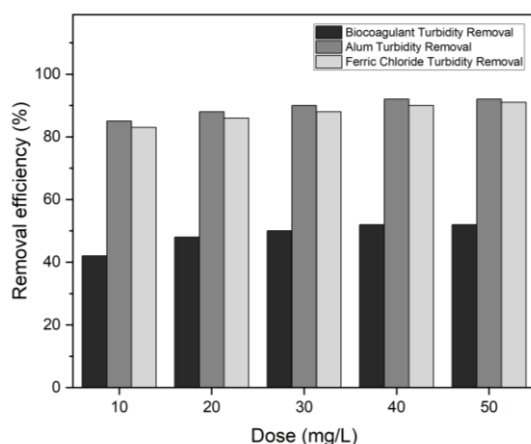
**Figure 3.** TSS Removal

### 3.3. TSS Reduction

*Moringa oleifera* seed extract achieved significant TSS reduction, with efficiency increasing from 65% at 1 g/L to a maximum of 75% at 4 g/L (**Fig 3**). The results confirm its effectiveness in aggregating and settling suspended particles, as previously demonstrated by Jahn (1988) and Muyibi and Evison (1995) [15], [20]. The TSS reduction performance of moringa seed extract was comparable to alum and ferric chloride, suggesting its potential as a sustainable alternative for suspended solids removal, as supported by Al-Jadabi et al. (2023)[21].

### 3.4. Comparison with Conventional Coagulants

Although moringa seed extract showed promising results, its turbidity removal efficiency (52%) was lower than alum (92%) and ferric chloride (90%). This performance gap aligns with the findings of Desta and Bote. (2021) [22], who emphasized the superior coagulation properties of chemical coagulants. However, moringa seed extract offers unique advantages, such as biodegradability, low toxicity, and reduced sludge generation [23], [24]. These attributes make it a viable alternative in resource-limited settings, as noted by Sanghi et al. (2006) [25].



**Figure 4.** Comparison with Conventional Coagulants

The results indicate that moringa seed extract can be effectively used as a biocoagulant for laundry wastewater,

particularly in reducing TSS. However, its moderate performance in turbidity and COD removal suggests that it may be best utilized in combination with other treatment processes, such as biological or advanced oxidation methods, to achieve higher efficiency. Further studies could explore the optimization of moringa seed extract through chemical modification or advanced preparation techniques, as suggested by Muyibi et al. (2003) and Tong et al. (2022) [1], [26].

The sustainability of moringa seed extract aligns with global efforts to reduce the environmental footprint of wastewater treatment. Its wide availability in tropical regions and biodegradability offer a cost-effective and eco-friendly solution for small- and medium-scale operations, as highlighted by Ndabigengesere et al. (1995) and Rahmadyanti (2018) [16], [27].

## 4. CONCLUSION

This study demonstrates the potential of *Moringa oleifera* seed extract as a natural biocoagulant for the treatment of synthetic laundry wastewater. The results showed that a dose of 4 g/L was optimal, achieving 52% turbidity removal, 35% COD reduction, and 75% TSS reduction. While its turbidity removal efficiency was lower than conventional coagulants such as alum and ferric chloride, its performance in reducing TSS was comparable, making it a viable alternative for specific applications.

The advantages of *Moringa oleifera* seed extract include its biodegradability, non-toxicity, and availability in tropical regions, which make it an environmentally sustainable and cost-effective option for wastewater treatment. However, its moderate COD and turbidity removal suggest that it is best employed in conjunction with other treatment methods, such as biological processes or advanced oxidation techniques. Additionally, exploring its application in treating various types of wastewater and integrating it into scalable treatment systems could broaden its practical utility.

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