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# EVALUATION OF MORINGA OLEIFERA SEED EXTRACT AS A NATURAL COAGULANT FOR TURBIDITY REMOVAL IN WASTEWATER TREATMENT APPLICATIONS

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**Abstract**—The escalating global water crisis, driven by industrialization and population growth, necessitates the development of sustainable, non-toxic, and cost-effective wastewater treatment technologies. Turbidity, a primary indicator of water quality, is typically mitigated through coagulation-flocculation processes using chemical agents like aluminum sulfate (alum). However, the environmental and health drawbacks associated with synthetic coagulants, including residual toxicity and voluminous sludge production, have catalyzed research into bio-based alternatives. This study evaluates the efficacy of Moringa oleifera seed extract as a natural coagulant. Moringa oleifera, often termed the "Miracle Tree," contains water-soluble cationic proteins (MOCP) that act as natural polyelectrolytes, facilitating particle aggregation via charge neutralization, adsorption, and polymer bridging. Through systematic experimentation using a standard jar test apparatus, this research examines the influence of coagulant dosage, pH, and settling time on turbidity removal. Results indicate a peak removal efficiency of 92.0% at an optimal dosage of 250 mg/L and a removal efficiency of 93.3% at a near-neutral pH of 7.0. This report provides a comprehensive assessment of Moringa oleifera as a viable, eco-friendly substitute for conventional water treatment reagents in decentralized and rural settings.

**Keywords**—Moringa oleifera, natural coagulant, wastewater treatment, coagulation, cationic proteins, sustainable water treatment.

## I. INTRODUCTION

The Global Imperative for Sustainable Water Remediation Water serves as the foundational resource for human health, environmental stability, and economic prosperity. However, the contemporary era is marked by severe water quality deterioration resulting from rapid urbanization and industrial expansion. One of the most significant challenges in water management is the presence of turbidity, which is caused by suspended and colloidal particles such as silt, clay, organic matter, and microorganisms. High turbidity levels not only compromise the aesthetic value of water but also interfere with disinfection processes, effectively shielding pathogens and promoting the transport of heavy metals, which poses substantial public health risks [20,6]. The standard practice for removing these impurities is the coagulation–flocculation process, which involves the destabilization of colloidal particles and their subsequent aggregation into settleable flocs [8]. While chemical coagulants like aluminum sulfate and ferric chloride are highly effective due to their charge neutralization and hydrolysis effects, their usage is fraught with complications. These include the production of toxic metallic residues in treated water, the generation of large volumes of non-biodegradable sludge, and significant changes in the water's pH, which require additional chemical buffering [21,4]. Furthermore, the economic cost of synthetic chemicals and the environmental hazards of sludge disposal have shifted the focus of environmental engineering toward natural, plant-based coagulants [7]. Natural coagulants offer a sustainable alternative in alignment with the principles of green chemistry. These materials are generally non-toxic, biodegradable, locally available, and cost-effective [1].



Among the various botanical candidates, *Moringa oleifera* has emerged as the most promising due to its high coagulation efficiency and widespread distribution in tropical and subtropical regions [17,21]. This research seeks to bridge the gap between traditional knowledge and modern environmental technology by evaluating *Moringa oleifera* as a primary reagent for wastewater treatment [14].

## II. REVIEW OF LITERATURE

### **Taxonomical and Ethnobotanical Profile of *Moringa oleifera***

*Moringa oleifera* is a versatile, nutrient-rich plant belonging to the Moringaceae family [3,13]. Native to India, it has been cultivated globally across Asia, Latin America, Florida, the Caribbean, and the Pacific Islands [9,15]. The plant is known by various names, including the drumstick tree, radish tree, and ben oil tree, reflecting the physical characteristics of its pods and roots [3].

### **Diversity and Species Distribution**

The *Moringa* genus comprises 13 distinct species distributed across Southwest Asia, Africa, and Madagascar [13,9]. While *Moringa oleifera* is the most extensively researched, other species within the genus possess unique properties that contribute to regional biodiversity and traditional medicine [2]. The species *M. oleifera* is particularly noted for its drought resistance and rapid growth, which makes it an ideal resource for water-stressed regions [9,13]. Beyond its utility in water purification, the plant is a nutritional powerhouse, containing significant concentrations of Vitamin A, Vitamin C, potassium, and calcium [3,15]. It is frequently cited as containing twice the protein of yogurt, four times the Vitamin A of carrots, seven times the Vitamin C of oranges, and four times the calcium of milk [9].

### **Theoretical Mechanisms of Coagulation and Flocculation**

Coagulation-flocculation is a multi-step physicochemical process designed to destabilize colloidal suspensions. In aquatic environments, most suspended particles carry a negative surface charge, leading to electrostatic repulsion that keeps them in suspension. Effective treatment requires the introduction of agents that can neutralize these charges or physically bridge the particles to form larger aggregates [8,6].

### **Charge Neutralization and Adsorption**

The primary active agents in *Moringa oleifera* seeds are water-soluble cationic proteins, often referred to as *Moringa oleifera* cationic proteins (MOCP) [17,10]. These proteins possess a high density of positive charges, which interact with the negatively charged surfaces of colloidal particles like clay or bacteria. When the MOCP adsorbs onto the particle surface, it neutralizes the electrostatic repulsion,

allowing the particles to come close enough for van der Waals forces to initiate aggregation [18,21].

### **Polymer Bridging and Sweep Flocculation**

Beyond simple charge neutralization, the long-chain structure of the *Moringa* proteins enables polymer bridging. In this mechanism, a single protein chain can simultaneously adsorb onto multiple colloidal particles, forming a physical "bridge" that links them together. This creates larger, denser flocs that settle more rapidly under the influence of gravity. In some instances, as these larger flocs settle, they physically enmesh smaller particles in a process known as sweep flocculation, effectively clarifying the water [6,8].

### **Historical Development and Scientific Validation**

The exploration of *Moringa* as a coagulant has evolved through several decades of scientific scrutiny. Early studies established the foundational understanding that the active agents were indeed proteins [17]. Subsequent research revealed that extracting these proteins with a salt solution (NaCl) significantly improved their recovery and activity compared to simple aqueous extraction. This is due to the "salting-in" effect, where the presence of ions increases the solubility of the cationic proteins [18,10].

### **Materials and Methodological Framework**

The evaluation of *Moringa oleifera* seed extract was conducted through a standardized experimental protocol designed to simulate industrial wastewater treatment processes.

### **Coagulant Preparation**

The seeds were manually de-shelled to extract the kernels, which were then air-dried to remove moisture. These kernels were ground into a fine powder using a laboratory mill to maximize the surface area for protein extraction. Two extraction methods were evaluated: aqueous extraction (using distilled water) and salt-assisted extraction (using NaCl). The mixture was stirred continuously to facilitate the release of soluble proteins and then filtered to remove insoluble residues, resulting in a crude *Moringa* seed extract.

### **Wastewater Characterization**

Wastewater samples were collected from local sewage treatment plants to ensure realistic testing conditions. Initial characterization included the measurement of pH, Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and initial turbidity (measured in Nephelometric Turbidity Units, NTU) For the purpose of these experiments, the initial turbidity was standardized to approximately 150 NTU.



**Jar Test Experimental Procedure**

The coagulation-flocculation experiments utilized a jar test apparatus, allowing for the simultaneous testing of multiple variables. The procedure followed a three-phase approach:

**Rapid Mixing:** The wastewater was stirred at 230 rpm for 15 minutes immediately after the addition of the coagulant to ensure uniform dispersion and initiate particle destabilization.

**Slow Mixing:** The speed was reduced to 30 rpm for 15 minutes to facilitate inter-particle collisions and the growth of larger flocs through polymer bridging.

**Sedimentation:** The stirring was stopped, and the samples were allowed to settle for a period ranging from 10 to 60 minutes.

The effectiveness of the treatment was assessed by analyzing the supernatant for residual turbidity and calculating the removal efficiency relative to the initial values.

**III. RESULTS AND DISCUSSION: OPTIMIZATION OF COAGULATION PARAMETERS**

The efficiency of *Moringa oleifera* as a coagulant is highly sensitive to operational parameters. Systematic optimization of dosage, pH, and settling time is required to achieve maximum turbidity reduction.

**The Role of Coagulant Dosage**

The concentration of *Moringa* extract determines the number of active cationic sites available for interaction with colloidal particles. The relationship between dosage and removal efficiency follows a non-linear trend characterized by an optimal peak.

Table 1: Turbidity Removal Efficiency as a Function of *Moringa* Dosage\

Dose (mg/L)	Initial Turbidity(NTU)	Final Turbidity (NTU)	Removal Efficiency (%)
50	150	82	45.3
100	150	57	62.0
150	150	33	78.0
200	150	18	88.0
250	150	12	92.0
300	150	15	90.0
400	150	22	85.3
500	150	30	80.0

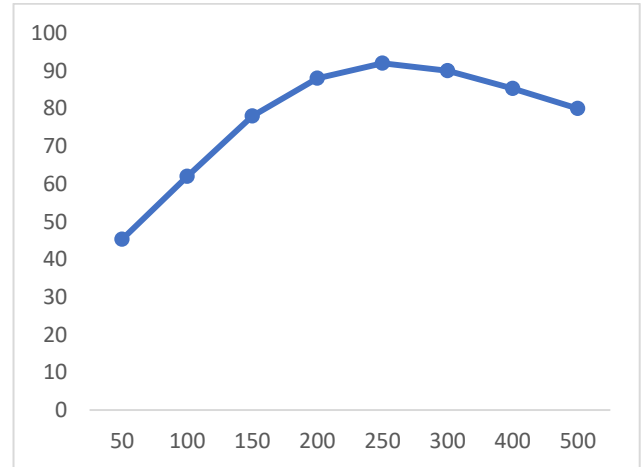


Figure 1: Consequence of coagulant dosage on turbidity elimination efficiency using *Moringa oleifera* seed extract.

As shown in Table 1, the removal efficiency increases as the dosage rises from 50 mg/L to the optimum of 250 mg/L, where a maximum removal of 92.0% is achieved. This reflects the progressive neutralization of particle surface charges. However, as the dosage increases beyond 250 mg/L, the removal efficiency begins to decline. This phenomenon is attributed to "particle restabilization" caused by "charge reversal". When an excess of cationic proteins is present, they impart a net positive charge to the colloidal particles, which re-establishes electrostatic repulsion and prevents the particles from aggregating [18,21].

**The Influence of pH on Coagulation Efficiency**

The pH of the medium affects the ionization of the functional groups on the *Moringa* protein chains, such as amine (-NH<sub>2</sub>) and carboxyl (-COOH) groups. This, in turn, dictates the strength of the electrostatic interaction between the coagulant and the particles (Okuda et al., 2001; Yin, 2010).

Table 2: Influence of System pH on Clarification Performance

pH	Initial Turbidity (NTU)	Final Turbidity (NTU)	Removal Efficiency (%)
4	150	45	70.0
5	150	27	82.0
6	150	15	90.0
7	150	10	93.3
8	150	14	90.7
9	150	23	84.7
10	150	33	78.0

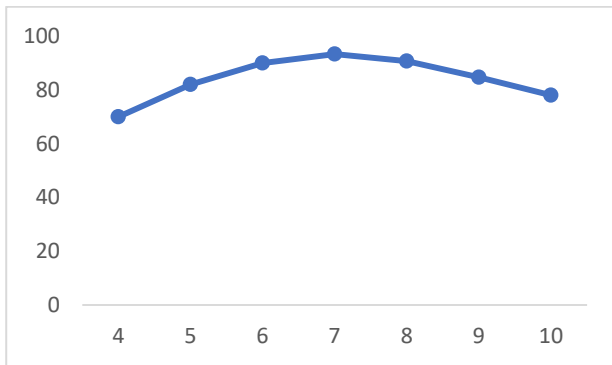


Figure 2: Effect of pH on turbidity removal efficiency using *Moringa oleifera* seed extract

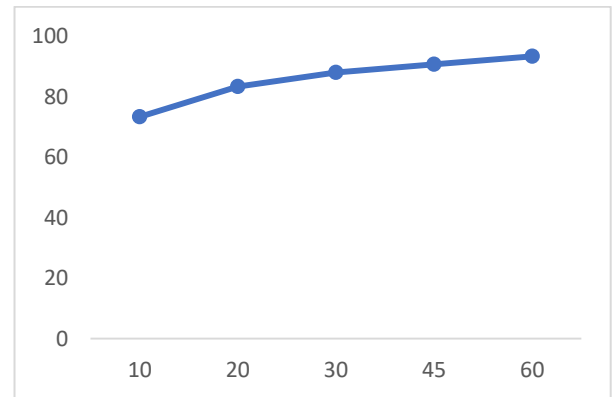


Figure 3: Effect of settling time on turbidity removal efficiency using *Moringa oleifera* seed extract.

Maximum efficiency (93.3%) was observed at a neutral pH of 7.0. At lower pH levels (pH 4), the efficiency was reduced (70.0%), likely due to the structural alteration of the protein molecules or excessive protonation that might inhibit optimal adsorption. Similarly, at highly alkaline levels (pH 10), the efficiency dropped to 78.0%. This decline is likely caused by the deprotonation of the amine groups, which reduces the positive charge density of the coagulant, thereby weakening its ability to neutralize negatively charged particles. The ability of *Moringa* to perform optimally at neutral pH is a significant advantage, as most natural water bodies and wastewaters fall within or near this range, reducing the need for chemical pH adjustment [18,21].

#### Settling Time and Sedimentation Dynamics

Settling time is a critical operational constraint that governs the physical separation of flocs from the clarified water. Sufficient time must be provided for the formed aggregates to overcome Brownian motion and settle under the influence of gravity [6,8].

Table 3: Influence of settling time on Clarification Performance

Settling Time (min)	Final Turbidity (NTU)	Removal Efficiency (%)
10	40	73.3
20	25	83.3
30	18	88.0
45	14	90.7
60	10	93.3

The data indicates that while substantial turbidity removal (73.3%) occurs within the first 10 minutes, a full hour is required to reach the maximum efficiency of 93.3%. This suggests that the flocs formed by *Moringa* continue to aggregate and densify during the quiescent period. The majority of the removal occurs within the first 30 minutes, confirming that the polymer bridging mechanism produces relatively stable and heavy flocs that settle efficiently.

#### Mechanistic Synergy

The research confirms that *Moringa* does not rely on a single pathway but rather a synergistic combination of mechanisms. The initial phase is dominated by charge neutralization, where cationic proteins reduce the zeta potential of colloidal particles. This is immediately followed by adsorption of protein molecules onto particle surfaces, and finally, polymer bridging, which builds the lattice-like structures observed as settleable flocs. This multi-layered mechanism explains why *Moringa* remains effective even in wastewater with variable organic loads [17,18].

#### Environmental and Socio-Economic Implications

The application of *Moringa oleifera* in water treatment transcends simple engineering; it addresses the broader goals of global sustainability and environmental justice.

#### Biodegradability and Reduced Ecological Footprint

The primary environmental advantage of *Moringa* is its inherent biodegradability. Conventional water treatment plants generate thousands of tons of metallic sludge annually, which often ends up in landfills. *Moringa*-based sludge is composed of plant proteins and organic matter that decompose naturally, reducing the long-term environmental burden. Additionally, studies have highlighted the antimicrobial properties of *Moringa* seeds, which can reduce the bacterial load in water, potentially decreasing the amount of chlorine required for secondary disinfection [1,4,7]



#### IV. FUTURE DIRECTIONS AND RESEARCH GAPS

While the laboratory-scale success of Moringa is well-documented, several hurdles remain for large-scale industrial adoption.

##### **Standardizing Extraction and Formulation**

One of the primary challenges is the variability in seed quality and protein concentration due to environmental factors like soil quality and seasonal changes. Further research is needed to develop standardized extraction protocols that ensure consistent coagulation activity. Additionally, the shelf life of the liquid extract is relatively short, often requiring usage within 24 hours to prevent microbial degradation of the active proteins. The development of stabilized or powdered extract forms could address this limitation [10,18].

##### **Hybrid and Advanced Systems**

Future studies should explore the integration of Moringa with modern technologies. Hybrid systems, which use Moringa in combination with low doses of chemical coagulants, could provide an optimal balance of efficiency and sustainability. Moreover, the application of nanotechnology—such as functionalizing nanoparticles with Moringa protein—could significantly enhance the removal of specific contaminants like heavy metals or pharmaceutical residues. Recent studies in 2026 have already begun exploring automated dosing systems using sensors to optimize the application of Moringa in real-time, pointing toward a future of "smart" bio-remediation [1,14].

##### **Final Synthesis and Recommendations**

The investigation into Moringa oleifera seed extract as a natural coagulant provides a robust scientific foundation for its use in wastewater treatment. The study has demonstrated that this plant-based agent is capable of achieving turbidity removal efficiencies exceeding 92% under optimized conditions of 250 mg/L dosage and neutral pH. Its performance is comparable to traditional chemical coagulants, while offering significant environmental benefits including biodegradability, non-toxicity, and minimal pH disruption [19,4].

For practitioners and policymakers, the following recommendations are provided based on the research findings:

- Moringa oleifera can be prioritized for household and small-scale water treatment systems in tropical regions where the plant is indigenous.
- Municipal treatment plants can consider Moringa as a co-coagulant to reduce their reliance on alum and decrease the volume of toxic sludge produced.

- Investment in local Moringa cultivation can serve a dual purpose: improving water security and providing nutritional supplements to local populations.

In conclusion, Moringa oleifera is not merely an ethnobotanical curiosity but a technically viable and environmentally responsible solution to the challenges of modern wastewater management. By leveraging the natural properties of the "Miracle Tree," we can advance toward a more sustainable and equitable future for global water remediation.

#### V. REFERENCES

- [1]. Alazaiza, M.Y.D., Alzghoul, T.M., Nassani, D.E., and Bashir, M.J.K. (2025). Natural Coagulants for Sustainable Wastewater Treatment: Current Global Research Trends. *Processes*, 13(6), 1754. <https://doi.org/10.3390/pr13061754>
- [2]. Abe, R., and Ohtani, K. (2013). An ethnobotanical study of medicinal plants and traditional therapies on Batan Island, the Philippines. *Journal of Ethnopharmacology*, 145, 554–565.
- [3]. Anwar, F., Latif, S., Ashraf, M., and Gilani, A.H. (2007). Moringa oleifera: a food plant with multiple medicinal uses. *Phytotherapy Research*, 21, 17–25.
- [4]. Ang, W.L., and Mohammad, A.W. (2020). State of the art and sustainability of natural coagulants in water and wastewater treatment. *Journal of Cleaner Production*, 262, 121267. <https://doi.org/10.1016/j.jclepro.2020.121267>.
- [5]. Bazrafshan, E., Mahvi, A.H., Nasser, S., and Shaiei, M. (2012). Performance evaluation of Moringa oleifera seed extract as a natural coagulant aid in removal of turbidity and bacteria from water. *Journal of Water Supply: Research and Technology–AQUA*, 61, 358–364.
- [6]. Bratby, J. (2016). *Coagulation and Flocculation in Water and Wastewater Treatment* (3rd ed.). IWA Publishing. <https://doi.org/10.2166/9781780407500>
- [7]. Choy, S.Y., Prasad, K.M.N., Wu, T.Y., Raghunandan, M.E., and Ramanan, R.N. (2014). Utilization of plant-based natural coagulants as future alternatives towards sustainable water clarification. *Journal of Environmental Sciences*, 26(11), 2178–2189. <https://doi.org/10.1016/j.jes.2014.09.024>
- [8]. Duan, J., and Gregory, J. (2003). Coagulation by hydrolysing metal salts. *Advances in Colloid and Interface Science*, 100–102, 475–502. [https://doi.org/10.1016/S0001-8686\(02\)00067-2](https://doi.org/10.1016/S0001-8686(02)00067-2)
- [9]. Fahey, J.W. (2005). Moringa oleifera: A review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. *Trees for Life Journal*, 1, 5.



- [10]. Ghebremichael, K.A., Gunaratna, K.R., Henriksson, H., Brumer, H., and Dalhammar, G. (2005). A simple purification and activity assay of the coagulant protein from *Moringa oleifera* seed. *Water Research*, 39(11), 2338–2344. <https://doi.org/10.1016/j.watres.2005.04.012>
- [11]. Katayon, S., Noor, M.J.M.M., Asma, M., Ghani, L.A.A., Thamer, A.M., Azni, I., Ahmad, J., Khor, B.C., and Suleyman, A.M. (2006). Effects of storage conditions of *Moringa oleifera* seeds on its performance in coagulation. *Bioresource Technology*, 97(13), 1455–1460. <https://doi.org/10.1016/j.biortech.2005.07.031>
- [12]. Lea, M. (2010). Bioremediation of turbid surface water using seed extract from *Moringa oleifera* Lam. *Current Protocols in Microbiology*, 16(1), 1G.2.1–1G.2.14. <https://doi.org/10.1002/9780471729259.mc01g02s16>
- [13]. Leone, A., Spada, A., Battezzati, A., et al. (2015). Cultivation, genetic, ethnopharmacology, phytochemistry and pharmacology of *Moringa oleifera* leaves: an overview. *International Journal of Molecular Sciences*, 16, 12791–12835.
- [14]. Lwasa, A., Mdee, O.J., Ntalikwa, J.W., et al. (2024). Performance analysis of plant-based coagulants in water purification: a review. *Discover Water*, 4, 108. <https://doi.org/10.1007/s43832-024-00171-0>
- [15]. Mahmood, K.T., Mugal, T., and Haq, I.U. (2010). *Moringa oleifera*: a natural gift—A review. *Journal of Pharmaceutical Sciences and Research*, 2, 775–781.
- [16]. Muyibi, S.A., and Evison, L.M. (1995). Optimizing physical parameters affecting coagulation of turbid water with *Moringa oleifera* seeds. *Water Research*, 29, 2689–2695.
- [17]. Ndabigengesere, A., Narasiah, K.S., and Talbot, B.G. (1995). Active agents and mechanism of coagulation of turbid waters using *Moringa oleifera*. *Water Research*, 29, 703–710. [https://doi.org/10.1016/0043-1354\(94\)00161-Y](https://doi.org/10.1016/0043-1354(94)00161-Y)
- [18]. Okuda, T., Baes, A.U., Nishijima, W., and Okada, M. (2001). Isolation and characterization of coagulant extracted from *Moringa oleifera* seed by salt solution. *Water Research*, 35(2), 405–410. [https://doi.org/10.1016/S0043-1354\(00\)00290-6](https://doi.org/10.1016/S0043-1354(00)00290-6)
- [19]. Pritchard, M., Craven, T., Mkandawire, T., Edmondson, A.S., and O’Neill, J.G. (2010). A comparison between *Moringa oleifera* and chemical coagulants in the purification of drinking water—An alternative sustainable solution for developing countries. *Physics and Chemistry of the Earth*, 35(13–14), 798–805. <https://doi.org/10.1016/j.pce.2010.07.014>
- [20]. World Health Organization. (2022). *Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First and Second Addenda*. World Health Organization.
- [21]. Yin, C.Y. (2010). Emerging usage of plant-based coagulants for water and wastewater treatment. *Process Biochemistry*, 45(9), 1437–1444. <https://doi.org/10.1016/j.procbio.2010.05.030>

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