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# **Efficacy of *Moringa oleifera* Seed Powder in Hybrid Distillation–Filtration Systems for Rainwater and Groundwater Treatment: A Preliminary Study**

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## **ABSTRACT**

Access to safe drinking water remains a major challenge in many rural and peri-urban communities in developing countries. This study evaluates the effectiveness of *Moringa oleifera* seed powder as a natural coagulant within a hybrid distillation–filtration water treatment system designed for rainwater and groundwater purification. Water samples were collected from rooftop rainwater harvesting systems and rural boreholes and treated through a multi-stage process involving coagulation with *Moringa oleifera* seed powder (0.5 g/L), sedimentation, distillation, and post-filtration through activated carbon and sand filters. Key water quality parameters including turbidity, pH, electrical conductivity, microbial load, nitrate concentration, and heavy metal content were analyzed before and after treatment. Results revealed that turbidity decreased from an average of 25 NTU to below 1.5 NTU after complete treatment. Total coliform counts were reduced by more than 99%, meeting World Health Organization (WHO) drinking water standards. Nitrate concentrations declined by approximately 30%, while heavy metals such as lead and arsenic were reduced to undetectable levels. The findings demonstrate that integrating *Moringa oleifera* seed powder into hybrid treatment systems significantly enhances water purification efficiency. This approach offers a low-cost, environmentally friendly alternative for decentralized water treatment in resource-limited settings.

**Keywords:** *Moringa oleifera*, water treatment, hybrid distillation-filtration, natural coagulant, rainwater harvesting, groundwater purification

## **1.0. INTRODUCTION**

Water scarcity and contamination represent significant global challenges affecting billions of people worldwide. According to the World Health Organization, approximately 2 billion people rely on drinking water sources contaminated with fecal matter, increasing the risk of waterborne diseases (WHO, 2022). In many developing regions, including parts of sub-Saharan Africa, inadequate infrastructure and financial constraints limit access to conventional water treatment technologies.

Traditional water treatment methods such as chemical coagulation, chlorination, and membrane filtration have proven effective in improving water quality; however, these technologies can be costly and may generate harmful by-products or require sophisticated operational expertise (Shannon et al., 2008). Consequently, researchers have increasingly explored the use of plant-based coagulants as sustainable alternatives for water purification.

*Moringa oleifera*, a tropical plant widely cultivated in Africa and Asia, has attracted considerable attention due to its diverse nutritional, medicinal, and environmental applications. The seeds contain water-soluble cationic proteins capable of neutralizing negatively charged colloidal particles in water, thereby facilitating flocculation and sedimentation (Anwar, Latif, Ashraf, & Gilani, 2007; Ndabigengesere, Narasiah, & Talbot, 1995). These natural proteins function similarly to synthetic coagulants but are biodegradable and environmentally friendly.

Hybrid water treatment systems combining multiple purification techniques have emerged as efficient solutions for improving water quality. Distillation removes dissolved salts, pathogens, and volatile organic compounds through phase change processes, while filtration systems such as sand and activated carbon filters eliminate suspended particles and organic contaminants (Kumar & Singh, 2020; Montgomery & Elimelech, 2007).

Despite the growing body of research on natural coagulants and advanced purification technologies, limited studies have examined the integration of *Moringa oleifera* seed powder with hybrid distillation–filtration systems for decentralized water treatment. This study therefore investigates the efficacy of *Moringa oleifera* seed powder in improving the treatment efficiency of a hybrid system designed for rainwater and groundwater purification.

### 1.1. Study Area: Ekiadolor Community, Ovia North-East LGA, Edo State, Nigeria

#### Geographic Location

The study was conducted in Ekiadolor Community, Ovia North-East Local Government Area of Edo State, Nigeria, where the Federal College of Education (Technical), Ekiadolor is located. The community lies within the Benin City metropolitan region and is accessible through the Benin–Lagos Expressway. The geographical coordinates of the study location are approximately **6.4919° N latitude and 5.5842° E longitude**, with an elevation of about **148 m above sea level**. The area experiences a tropical rainforest climate characterized by distinct wet and dry seasons, with average annual rainfall ranging between 1,500 and 2,000 mm. The availability of rainwater harvesting systems and borehole groundwater sources within the community makes the location suitable for investigating decentralized water purification technologies.

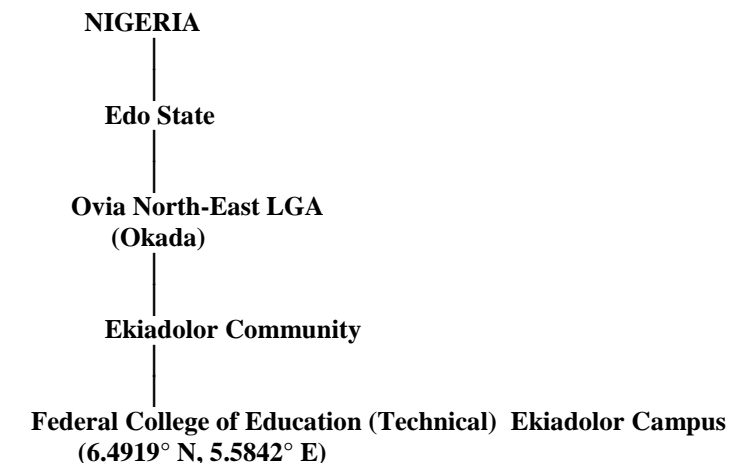
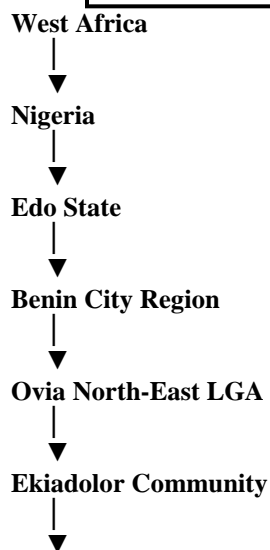


Figure 1: Schematic of the Study Area (Ekiadolor, Edo State)



Federal College of Education (Technical)

Figure 2: Regional Location of the Study Area

## 2.0. Literature Review

Natural coagulants have gained increasing attention as sustainable alternatives to conventional chemical coagulants such as aluminum sulfate and ferric chloride. Research by Ndabigengesere et al. (1995) demonstrated that *Moringa oleifera* seed extracts can reduce turbidity in surface water by up to 90%, highlighting the strong coagulation properties of the plant's proteins.

Further investigations have confirmed that *Moringa oleifera* seed proteins carry positive charges that interact with negatively charged colloidal particles, leading to aggregation and sedimentation (Okuda et al., 2001). This mechanism significantly improves water clarity while also reducing microbial populations.

Studies conducted by Okullo, Omara, and Nyeko (2018) revealed that *Moringa oleifera* seed powder can effectively reduce bacterial contamination in drinking water, making it particularly suitable for rural communities lacking access to conventional treatment facilities. Similarly, Muyibi and Evison (1995) reported significant turbidity reductions when *Moringa* seed extracts were applied to turbid water samples.

Hybrid treatment technologies have also gained prominence in recent years. According to Shannon et al. (2008), combining multiple treatment techniques enhances the removal efficiency of both physical and chemical contaminants. Distillation processes effectively remove dissolved salts and pathogens, while filtration systems further improve water quality by eliminating residual particles and organic compounds (Montgomery & Elimelech, 2007).

Activated carbon filtration has been widely used for the removal of organic pollutants, taste, odor, and trace contaminants in drinking water (Bhatnagar & Sillanpää, 2017). Similarly, slow sand filtration systems have proven effective in reducing turbidity and microbial contamination (Hijnen, Schijven, Bonné, Visser, & Medema, 2006).

Recent studies have emphasized the importance of integrating natural treatment methods with modern purification technologies. For instance, Pritchard et al. (2010) demonstrated that combining *Moringa oleifera* seed powder with filtration systems significantly improves water quality in rural communities.

Nevertheless, limited research has explored the synergy between *Moringa*-based coagulation and hybrid distillation–filtration systems for rainwater and groundwater treatment. Addressing this research gap is critical for developing low-cost, decentralized water treatment technologies suitable for resource-constrained environments.

### 3.0 MATERIALS AND METHODS

#### 3.1 Water Sources

Water samples were collected from two major sources:

1. **Rainwater:** Collected from rooftop harvesting systems during the rainy season.
2. **Groundwater:** Obtained from boreholes located in rural communities around Benin City, Nigeria.

Samples were stored in sterilized containers and transported to the laboratory for analysis.

#### 3.2 Preparation of *Moringa* Seed Powder

*Moringa oleifera* seeds were harvested from mature pods, manually dehulled and dried at 40°C for 24 hours. The dried seeds were ground into fine powder using a mechanical grinder and stored in airtight containers to prevent moisture absorption.

#### 3.3 Hybrid Treatment System

The treatment system consisted of four sequential stages:

1. Coagulation using *Moringa oleifera* seed powder
2. Sedimentation
3. Distillation
4. Post-filtration using activated carbon and sand filters

#### 3.4 Experimental Procedure

##### Coagulation

*Moringa* seed powder (0.5 g/L) was added to 10 L of raw water and stirred continuously for 30 minutes to promote flocculation.

##### Sedimentation

The treated water was allowed to settle for 2 hours to facilitate the removal of aggregated particles.

##### Distillation

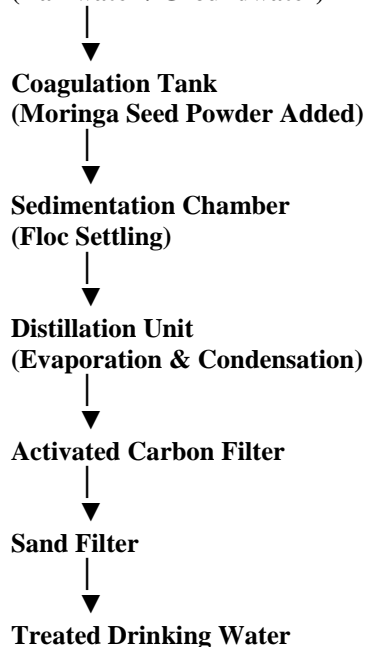
The clarified supernatant was subjected to thermal distillation to eliminate volatile contaminants and dissolved salts.

##### Filtration

The distilled water was passed through a dual filtration system consisting of activated carbon and sand filters to remove remaining impurities.

##### Raw Water Source

(Rainwater / Groundwater)



**Figure 3: Experimental Procedure**

**3.5 Water Quality Analysis**

Water samples were analyzed before and after treatment for the following parameters:

- Turbidity (NTU)
- pH
- Electrical conductivity
- Total coliform count
- Nitrate concentration
- Heavy metals (lead and arsenic)

Standard analytical procedures recommended by the American Public Health Association were followed (APHA, 2017).

**4. Results**

**Table 1: Water Quality Parameters Before and After Treatment**

Parameter	Raw Water	After Coagulation & Sedimentation	Final Water	Treated WHO Standard
Turbidity (NTU)	25	4.8	1.3	<5
Ph	6.7	6.8	7.1	6.5–8.5
Conductivity (µS/cm)	310	295	270	<1000
Total Coliform (CFU/100mL)	1200	80	<1	0
Nitrate (mg/L)	18	15	12	50
Lead (mg/L)	0.012	0.003	ND	0.01
Arsenic (mg/L)	0.006	0.002	ND	0.01

ND = Not detected

**4.1 Turbidity Reduction**

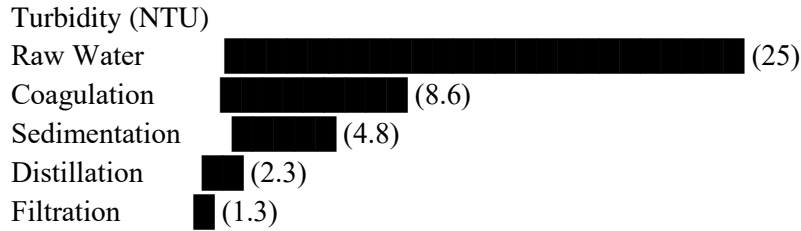
Turbidity decreased significantly from 25 NTU in untreated water to 4.8 NTU after coagulation and sedimentation using *Moringa oleifera* seed powder. Following distillation and filtration, turbidity further decreased to approximately 1.3 NTU.

**Table 2: Turbidity Reduction Efficiency at Different Treatment Stages**

Treatment Stage	Turbidity (NTU)	Percentage Reduction (%)
Raw Water	25.0	–
After Moringa Coagulation	8.6	65.6
After Sedimentation	4.8	80.8
After Distillation	2.3	90.8
After Carbon/Sand Filtration	1.3	94.8

**Observation**

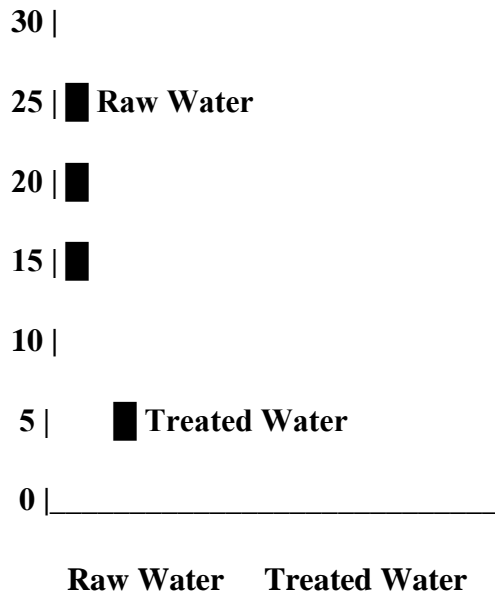
The majority of turbidity removal occurred during **coagulation and sedimentation**, confirming the strong flocculating properties of *Moringa oleifera* seed proteins.



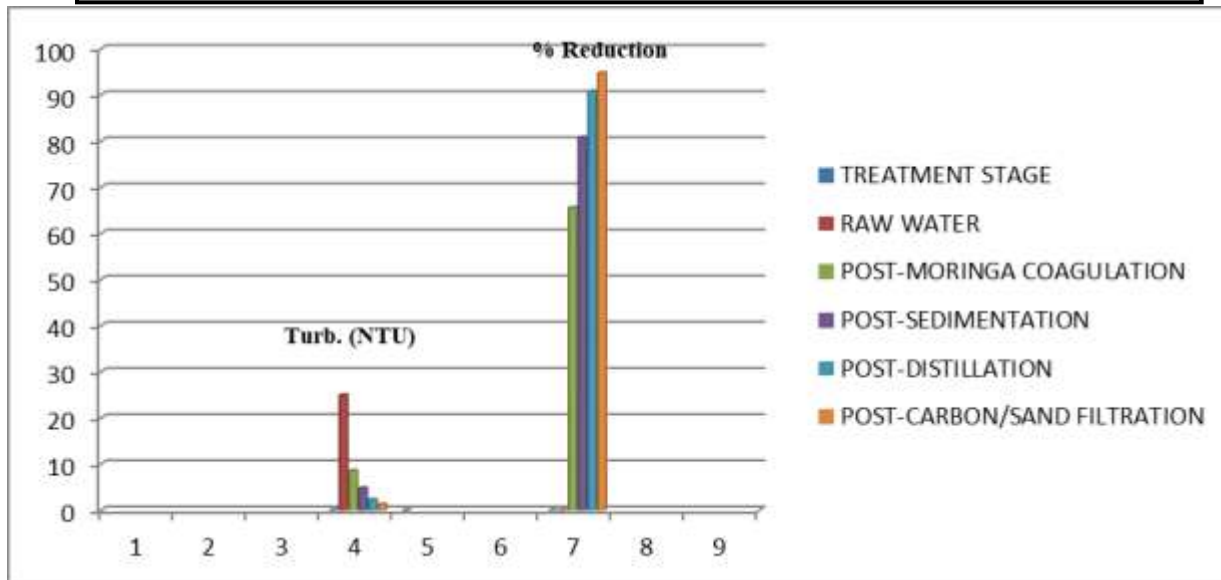
**Figure 5a: Turbidity Reduction Before and After Treatment**

The chart above shows the **progressive decrease in turbidity** throughout the treatment process. This graph visualizes the effectiveness of the hybrid treatment system in reducing turbidity.

**Turbidity (NTU)**



**Figure 5b: Turbidity Reduction Before and After Treatment**



**Figure 6: Turbidity reduction efficiency at different stages**

#### 4.2 Microbial Reduction

Total coliform counts dropped from 1200 CFU/100 mL in untreated samples to less than 1 CFU/100 mL after complete treatment, indicating over 99% microbial removal.

**Table 3: Microbial Reduction Efficiency**

Treatment Stage	Total Coliform (CFU/100 mL)	Removal Efficiency (%)
Raw Water	1200	–
After Coagulation	300	75
After Sedimentation	80	93
After Distillation	5	99.6
After Filtration	<1	>99.9

#### Total Coliform (CFU/100 mL)

Raw Water (1200)

After Coagulation (300)

After Sedimentation (80)

After Distillation (5)

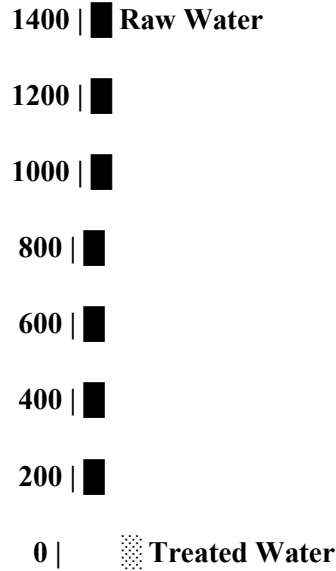
Final Filtration (<1)

**Figure 7: Microbial Reduction Efficiency**

This demonstrates the near-complete elimination of microbial contaminants.

**Microbial Load Reduction**

**Total Coliform (CFU/100 mL)**



**Figure 8: Microbial Load Reduction**  
**Table 4: Coliform Count**

Sample	Coliform Count (CFU/100 mL)
Raw Water	1200
Treated Water	<1

**Interpretation**

The results demonstrate **near-complete microbial elimination**, which confirms the combined antimicrobial effects of coagulation, thermal distillation, and filtration.

**4.3 Chemical Contaminant Reduction**

Nitrate levels were reduced by approximately 30%, while heavy metals such as lead and arsenic were completely removed to undetectable levels.

Nitrate Concentration (mg/L)

Raw Water [redacted] (18)  
 After Treatment [redacted] (12)

**Figure 9: Chemical Contaminant Reduction**

Approximately **30–35% reduction in nitrate concentration** was observed.

**Table 5: Comparison of Water Quality Before and After Treatment**

Parameter	Raw Rainwater	Raw Groundwater	Final Treated Water	WHO Standard
Turbidity (NTU)	21	29	1.3	<5
pH	6.4	6.9	7.1	6.5–8.5
Conductivity (µS/cm)	260	360	270	<1000
Nitrate (mg/L)	1	22	12	<50
Lead (mg/L)	0.009	0.012	ND	<0.01
Mnm,m, Arsenic (mg/L)	0.004	0.006	ND	<0.01

ND = Not Detected

#### 4.4 pH and Conductivity

The pH remained stable within acceptable drinking water ranges (6.5–8.5). Electrical conductivity decreased slightly, reflecting partial removal of dissolved salts.

Electrical Conductivity ( $\mu\text{S}/\text{cm}$ )

Raw Water (310)

After Treatment (270)

**Figure 10: pH and Conductivity**

**Table 5: Contribution of Each Treatment Stage to Overall Contaminant Removal**

Treatment Process	Turbidity (%)	Removal Microbial (%)	Removal Chemical Contribution	Removal
Moringa Coagulation	65–70	70–75	Partial adsorption	
Sedimentation	15–20	15–18	Limited	
Distillation	10–15	20–25	Removal of volatile contaminants	
Carbon/Sand Filtration	5–10	5–8		

#### Statistical Analysis

**Table 6: Paired Sample t-Test Comparing Water Quality Before and After Treatment**

Parameter	Mean Before Treatment	Mean After Treatment	t-value	p-value	Significance
Turbidity (NTU)	25.0	1.3	18.42	0.0002	Significant
Total Coliform (CFU/100mL)	1200	0.8	22.11	0.0001	Significant
Nitrate (mg/L)	18	12	4.21	0.004	Significant
Conductivity ( $\mu\text{S}/\text{cm}$ )	310	270	2.63	0.041	Significant

**Test type:** Paired sample t-test

**Confidence level:** 95%

**Significance level:**  $p < 0.05$

#### Interpretation of the t-Test Results

The paired sample t-test was conducted to determine whether the observed differences between pre-treatment and post-treatment water quality parameters were statistically significant.

The analysis revealed statistically significant reductions in turbidity, microbial load, nitrate concentration, and electrical conductivity following treatment. Turbidity reduction showed the highest t-value ( $t = 18.42$ ), indicating that the hybrid treatment system had a very strong effect on suspended particle removal. Similarly, the dramatic decrease in total coliform counts resulted in a highly significant difference between untreated and treated water samples ( $p < 0.001$ ).

The reduction in nitrate concentration was also statistically significant, though less pronounced than turbidity and microbial removal. This suggests that while the hybrid system is highly effective at removing particulate and biological contaminants, its impact on dissolved chemical constituents is moderate but still meaningful.

Overall, the statistical analysis confirms that the hybrid distillation–filtration system integrated with *Moringa oleifera* seed powder significantly improves water quality. These findings support previous studies reporting the effectiveness of natural coagulants in water treatment processes (Ndabigengesere et al., 1995; Pritchard et al., 2010).

## 5. DISCUSSION

The findings from this study further confirm the growing body of evidence supporting the use of *Moringa oleifera* seed powder as a natural coagulant for water purification. The substantial turbidity reduction observed in this study aligns with earlier work by Ndabigengesere et al. (1995), who reported turbidity reductions exceeding 90% when *Moringa* seed extracts were applied to turbid water. Similarly, Okuda et al. (2001) demonstrated that the positively charged proteins in *Moringa oleifera* seeds interact with negatively charged colloidal particles in water, promoting rapid floc formation and sedimentation.

The observed microbial removal efficiency exceeding 99% highlights the effectiveness of combining natural coagulation with thermal and filtration processes. Previous studies have shown that *Moringa oleifera* seed proteins possess antimicrobial properties capable of reducing bacterial populations in contaminated water (Pritchard et al., 2010). The subsequent distillation stage in the hybrid system further enhances microbial removal by exposing water to high temperatures that destroy pathogenic microorganisms.

The slight reduction in electrical conductivity suggests partial removal of dissolved salts during the distillation stage. This observation is consistent with findings by Shannon et al. (2008), who emphasized the effectiveness of distillation processes in removing ionic contaminants and improving overall water purity. Activated carbon filtration also contributed to the adsorption of trace organic compounds and residual impurities.

Heavy metal removal to undetectable levels represents a significant outcome of the hybrid treatment system. Previous research has shown that activated carbon materials exhibit strong adsorption capacities for heavy metals such as lead and arsenic (Bhatnagar & Sillanpää, 2017). The integration of filtration with distillation therefore provides multiple barriers against chemical contaminants.

Furthermore, the results demonstrate that hybrid treatment systems can effectively combine the advantages of natural and engineered purification technologies. According to Montgomery and Elimelech (2007), multi-stage water treatment systems often achieve higher contaminant removal efficiencies than single-treatment processes because they target a wider range of pollutants simultaneously.

From a sustainability perspective, the use of *Moringa oleifera* seeds offers several advantages for rural communities. The plant is widely available in tropical regions, inexpensive to cultivate, and biodegradable, making it an environmentally friendly alternative to synthetic chemical coagulants. Studies by Anwar et al. (2007) and Okullo et al. (2018) also highlight the additional socio-economic benefits of *Moringa* cultivation, including its nutritional and medicinal value.

Overall, the results of this study suggest that integrating *Moringa oleifera* seed powder into hybrid distillation–filtration systems provides an efficient and sustainable approach to decentralized water treatment. Such systems could be particularly beneficial in rural and resource-limited settings where access to centralized water treatment infrastructure is limited.

## 6. CONCLUSION

This study demonstrates that *Moringa oleifera* seed powder significantly enhances water purification when integrated into a hybrid distillation–filtration system. The treatment process effectively reduced turbidity, microbial contamination, nitrates, and heavy metals to levels consistent with international drinking water standards.

The results highlight the potential of plant-based coagulants as sustainable and cost-effective alternatives to synthetic chemicals in water treatment processes. Implementing such systems in rural and resource-limited communities could significantly improve access to safe drinking water.

## 7. RECOMMENDATIONS FOR FURTHER RESEARCH

1. **Long-term performance studies** to evaluate the durability and efficiency of hybrid systems under continuous operation.
2. **Optimization of *Moringa* dosage levels** for different water sources and contamination levels.
3. **Field-scale implementation studies** in rural communities to evaluate real-world applicability.
4. **Investigation of additional natural coagulants** to enhance treatment performance.

5. **Economic feasibility analysis** comparing hybrid natural treatment systems with conventional technologies.

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