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Application of Eco-Friendly Coagulants in Waste Water Treatment

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Abstract: ***The high cost associated with chemically treated coagulants has made access to clean water a major challenge in rural areas. Consequently, many rural populations are compelled to depend on easily accessible but low-quality water sources, thereby increasing their vulnerability to waterborne diseases.***
This study aims to evaluate the coagulation and adsorption efficiency of various low-cost, eco-friendly, and locally available natural coagulants-specifically Moringa oleifera seed powder, extract, and banana peel powder-as sustainable alternatives to conventional chemical coagulants such as alum or ferric chloride.
Experimental investigations and literature surveys consistently highlight Moringa oleifera seeds as the most effective among natural coagulants, due to their high cationic polyelectrolyte content, which facilitates the aggregation and sedimentation of suspended particles. Preliminary results from this project confirm that Moringa oleifera demonstrates superior adsorption equilibrium and turbidity removal efficiency when compared to other natural agents under controlled conditions.
This study underscores the potential of utilizing bio-coagulants in decentralized water treatment systems, especially in resourcelimited settings. The findings are expected to promote sustainable water purification practices by demonstrating that natural coagulants can achieve water quality improvements comparable to those of synthetic coagulants, while minimizing environmental and health-related side effects.
Keywords: Natural coagulants, Moringa oleifera, Banana peel powder, Turbidity removal, Adsorption equilibrium, Bio-coagulants, Decentralized water treatment, Rural water purification, Sustainable water treatment.

I. INTRODUCTION

Water is one of the most vital natural resources for the survival of humans and all living organisms. It is essential not only for drinking and domestic purposes but also for agriculture, industry, power generation, and maintaining ecological balance. However, rapid population growth, urbanization, and industrialization have significantly increased the demand for clean water while simultaneously contributing to the pollution of natural water bodies.

Human activities such as domestic sewage discharge, industrial effluents, agricultural runoff, and improper waste disposal convert valuable freshwater resources into wastewater containing suspended solids, dissolved salts, organic matter, microorganisms, and harmful chemicals. High turbidity caused by colloidal and suspended particles reduces water clarity and safety, making proper treatment necessary before reuse or discharge.

Coagulation and flocculation are among the oldest and most widely used methods in wastewater treatment for removing turbidity and colloidal impurities. Colloidal particles remain stable in water due to their surface electrical charges, but the addition of a coagulant neutralizes these charges, allowing particles to aggregate into larger flocs that can easily settle. Traditionally, chemical coagulants such as alum and iron salts have been widely used because of their effectiveness and low cost. However, prolonged use of aluminium-based coagulants has raised health concerns, including possible links to gastrointestinal issues, memory loss, and reduced energy levels, prompting the search for safer and more sustainable alternatives.

Natural coagulants have recently gained attention because they are biodegradable, renewable, eco-friendly, and safe for human health. Plant-based materials such as Moringa oleifera seeds and banana peels contain proteins and polysaccharides that exhibit strong coagulating properties.

The present study compares the performance of Moringa oleifera seed powder and banana peel powder with alum to evaluate their effectiveness in turbidity removal. The study aims to promote sustainable water purification methods, utilize low-cost agricultural waste, and develop practical solutions suitable for rural and developing areas where chemical coagulants may be expensive or limited.

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II. NATURAL COAGULANTS

A. Banana Peel Powder

Fig .1 Unripen banana peel

Unripe banana peels constitute a significant portion of agricultural and household organic waste, especially in regions where bananas are widely consumed and processed. During food preparation and banana processing industries, large quantities of green banana peels are discarded, often ending up in open dumps or landfills. Improper disposal of this biodegradable waste can lead to unpleasant odours, attraction of pests, and increased organic load in the environment due to rapid decomposition. However, unripe banana peels are rich in natural polymers such as pectin, cellulose, and starch, which possess useful functional properties. Instead of being treated solely as waste, they can be effectively valorized as low-cost bio-materials for applications such as wastewater treatment, thereby reducing environmental burden while promoting sustainable waste management.

1) Characteristics of banana peel powder which could be used as natural coagulant.

- Contains natural biopolymers (cellulose, hemicellulose, pectin) that aid particle binding.
- Possesses negatively charged functional groups (-OH, -COOH) enabling adsorption of suspended particles.
- Has high surface area and porosity, improving floc formation. oRich in organic compounds that promote bridging between colloids
- Shows good turbidity and TSS removal efficiency.
- Biodegradable and eco-friendly, producing less chemical sludge. oLow cost and easily available agricultural waste material

2) Procedures to make banana peel powder.

- Collect fresh banana peels and remove any pulp.
- Wash peels thoroughly with tap water.
- Rinse again using distilled water to remove impurities.
- Cut the peels into small uniform pieces.
- Air-dry the pieces for a few day (3-4 days)in the sunlight.
- Grind the dried peels using a mixer or grinder.
- Sieve the powder to obtain fine particles.
- Store the banana peel powder in an airtight container

Fig .2 Unripen banana peel powder

B. Moringa Oleifera Seed Powder

Fig .3 Moringa seed

Moringa oleifera (commonly known as the drumstick tree) seed powder is increasingly recognized for its potential as a natural bio-fertilizer and soil conditioner in agriculture, although the seeds are traditionally valued mainly for their edible and nutritional benefits in regions where the plant is widely cultivated. The seeds are rich in proteins, healthy oils,vitamins, minerals, and natural plant growth hormones especially cytokinins such as zeatin along with amino acids, antioxidants,and micronutrients. In many households, attention remains focused on their food value, often overlooking their additional functional properties. When applied to soil or crops, Moringa seed powder promotes seed germination, enhances root and leaf development, increases crop yield, stimulates beneficial soil microbial activity, and improves nutrient absorption by plants. Moreover, the presence of natural cationic proteins gives the seeds strong coagulating ability, making them useful not only in agriculture but also as an eco-friendly material for water and wastewater treatment.

Due to their biodegradable nature, low cost, local availability, and ability to improve soil fertility over time, Moringa seeds provide a sustainable alternative that reduces dependence on chemical fertilizers while supporting long-term environmental and soil health.

1) Characteristics of Moringa oleifera seed powder which could be used as natural coagulant.

- Contains water-soluble cationic proteins that act as natural coagulants.
- Positively charged proteins neutralize negatively charged colloidal particles.
- Effective in reducing turbidity and suspended solids.
- Works well over a wide pH range of water.
- Produces biodegradable and non-toxic sludge.
- Locally available, low-cost and eco-friendly.

2) Procedure of making moringa seed powder from raw seeds

- Collect mature, dry Moringa oleifera seeds.
- Remove the seed coats to obtain clean kernels.
- Wash the kernels with distilled water.
- Air-dry or oven-dry at 50-60 °C until fully dry.
- Grind the dried kernels into a fine powder.
- Sieve the powder to ensure uniform particle size.
- Store the Moringa seed powder in an airtight container.

Fig .4 Moringa seed powder

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III. WASTE WATER SAMPLES

A. Diary Industry Wastewater

	ph	turbidity
alum		
0 mg	3.305	472
20mg	3.300	289
40mg	3.206	197
Banana peel powder	Ph	Turbidity
0mg	3.305	472
20mg	3.350	233
40mg	3.380	187
Moringa oleifera seed powder		
0mg	3.305	472
20mg	3.380	233
40mg	3.380	187

Due to the inherently acidic nature of alum (aluminium sulphate), its addition to dairy wastewater tends to lower the pH of the treated water, making it more acidic. Dairy effluent already contains organic acids and dissolved solids, and further acidification during alum treatment can adversely affect downstream biological processes and may require additional pH correction. In contrast, natural coagulants such as Moringa oleifera seed powder and banana peel powder generally have a milder impact on pH and help maintain the water closer to neutral conditions. Therefore, natural coagulants are often more effective and environmentally favourable in this stage, as they achieve turbidity removal while minimizing excessive acidification of dairy wastewater

B. Polluted Pond Water Which Is Polluted By Unknown Pollutants

	Ph	Turbidity
alum		
0 mg	5.9	6.8
20mg	3.87	6.8
Banana peel powder and moringa oleifera seed powder		
0mg	5.9	6.8
20mg	6.87	6.8

This polluted pond water contains an unknown pollutant. Both the natural coagulants were similar in reaction with polluted pond sample and during the procedure of its treatment we can do ph stabilization by our coagulant along with lime stabilization.

C. Domestic Waste Water Or Grey Water

1) Grey Water (Ph =5.4)

	Ph	Turbidity
alum		
0 mg	5.405	303
20mg	5.060	49
40mg	3.900	18.7
Banana peel powder		
0mg	5.405	303
20mg	6.120	189
40mg	6.620	70
Moringa oleifera seed powder		
0mg	5.405	472
20mg	6.200	233
40mg	7.050	187

Among the three wastewater samples tested, the coagulants were applied to evaluate their treatment efficiency. The results indicated that domestic wastewater responded most effectively to the coagulation process compared to the other samples. Therefore, domestic wastewater was identified as the most suitable for treatment using the selected coagulants, and the detailed results corresponding to domestic wastewater are presented below

2) Grey Water (Ph=7)

Ph=7	Turbidity (NTU)
Moringa oleifera seed powder	
0mg	27
48mg	49
100mg	100
160mg	21
200mg	**18**
300mg	26

3) Grey Water(Ph=3.52)

	Ph	Turbidity (NTU)
Moringa oleifera seed powder		
0mg	3.52	184
200mg	4.40	41.2

The characteristics of greywater significantly influence the dosage of natural coagulant required for effective treatment. In particular, when the wastewater exhibits higher acidity, the coagulation process becomes less efficient, thereby necessitating the addition of a greater quantity of coagulant to achieve optimal turbidity and contaminant removal. Therefore, proper assessment of greywater quality parameters especially Ph is essential for determining the appropriate coagulant dosage and ensuring efficient treatment performance.

D. Sludge Handling

1) Land Application (as manure) If sludge is stabilized and pathogen-free. Used in agriculture as soil conditioner.

2) Composting

Mix with organic waste. Produces nutrient-rich compost.

3) Landfilling

Dispose in sanitary landfill.

Used when sludge is not suitable for farming.

4) Incineration

Burn at high temperature.

Reduces volume greatly.

Used when sludge contains harmful substances.

5) Co-processing in Cement Kiln Used as fuel in cement industries Used as fuel in cement industries

IV. CONCLUSIONS

Moringa oleifera seed powder has emerged as an effective natural coagulant for the treatment of domestic wastewater. It demonstrates a strong ability to reduce turbidity and suspended impurities while minimizing the environmental drawbacks commonly associated with conventional chemical coagulants. Its biodegradable and plant-based nature makes it especially suitable for sustainable greywater management.

One of the key advantages of using moringa seed powder is its ability to maintain the treated water closer to neutral pH. Unlike many chemical coagulants, it does not significantly acidify the wastewater, thereby reducing the need for additional pH correction. This contributes to a simpler, safer, and more environmentally friendly treatment process.

In contrast, alum presents a notable limitation in domestic wastewater treatment due to its acidic nature. The addition of alum often lowers the pH of the wastewater, which can lead to increased corrosivity, potential ecological stress, and the need for further chemical adjustment. This not only increases operational complexity but also affects the overall sustainability of the treatment system.

Furthermore, the optimal dosage for domestic wastewater treatment whether using natural or chemical coagulants depends strongly on the inherent characteristics of the sewage present in the greywater. Parameters such as initial turbidity, pH, organic load, and suspended solids concentration must be carefully evaluated to determine the appropriate coagulant dose. Proper characterization ensures efficient treatment performance while avoiding under- or over-dosing

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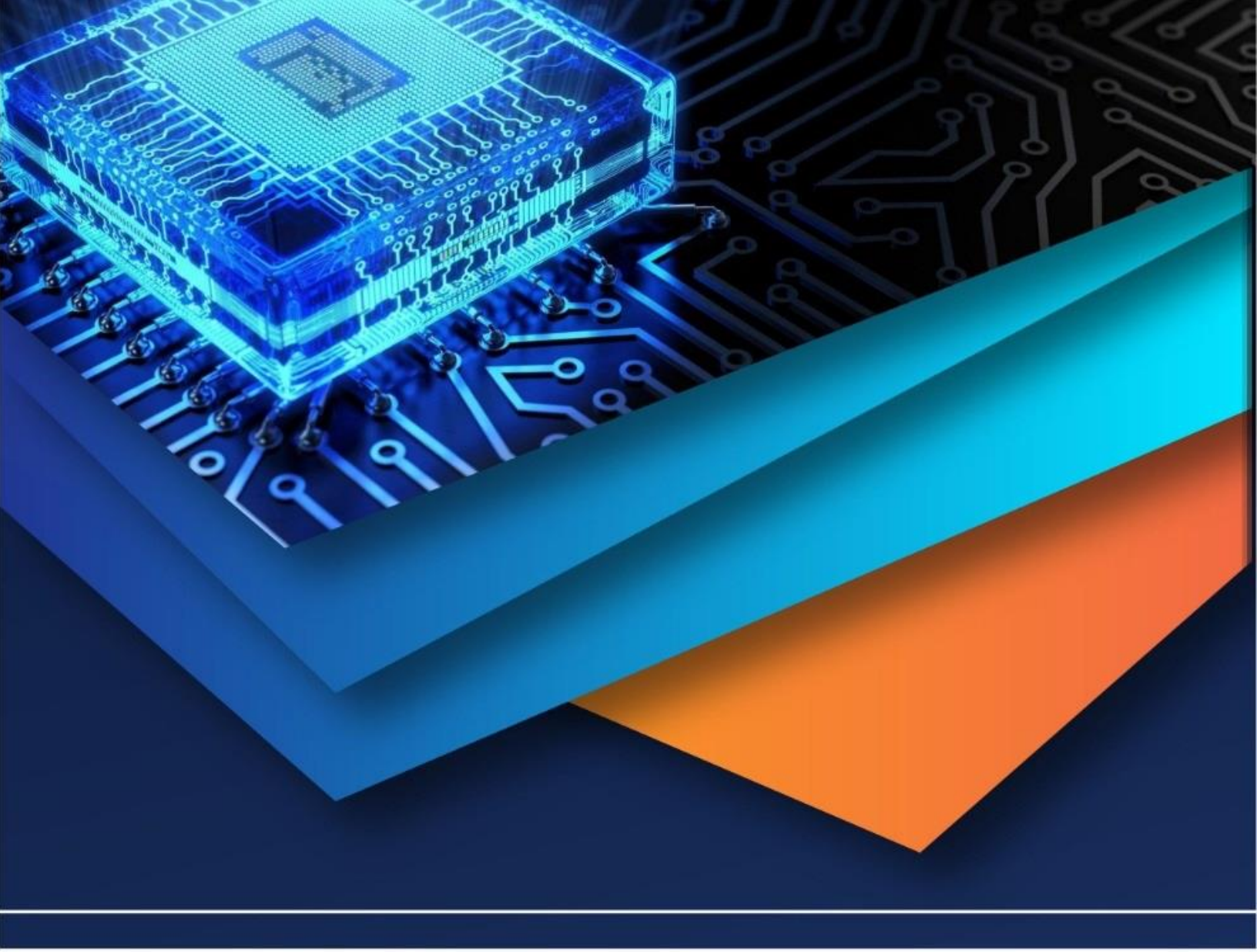

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