COMPARATIVE STUDY OF TURBIDITY REMOVAL IN TURBID WATER BY BIO-COAGULANTS

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***Abstract*—Turbidity is one of the most critical water quality parameters, and conventional chemical coagulants used for its removal pose significant health, environmental, and economic concerns. This study evaluates the effectiveness of three locally available bio-coagulants—Moringa oleifera (Moringa), Azadirachta indica (Neem), and Hibiscus esculentus (Okra) seed powder—individually and in blended proportions for turbidity removal from lake water. Water samples were collected from Chikkabanavara Lake, Bengaluru, and standard Jar Test experiments were conducted using dosages of 0.05 g, 0.10 g, 0.15 g, and 0.20 g per litre. Parameters, including turbidity (NTU) and pH, were measured before and after treatment. Results show that the optimum dosage for all coagulants was 0.1 g/L. Individual coagulants achieved turbidity removal efficiencies of 37.9% (Moringa), 34.64% (Neem), and 34.64% (Okra). Blended combinations significantly outperformed individual coagulants, with the ternary blend of Moringa + Okra + Neem (50:50:100) achieving the highest removal efficiency of 73.85%, reducing turbidity from 30.6 NTU to 8 NTU. These findings demonstrate that blended natural bio-coagulants offer a sustainable, cost-effective, and eco-friendly alternative for water purification, particularly for rural and developing communities.**

***Keywords*—Bio-coagulants; turbidity removal; Moringa oleifera; Azadirachta indica; Okra seed; Jar Test; natural water treatment; sustainable water purification.**

I. INTRODUCTION

Access to clean water remains a major global challenge, particularly in rapidly urbanizing regions where water bodies are subjected to increasing levels of contamination. Turbidity—the cloudiness or haziness of water caused by suspended particles such as silt, clay, organic matter, and microorganisms—is one of the most widely monitored indicators of water quality. High turbidity not only renders water aesthetically unacceptable but also poses serious public health risks by shielding pathogens from disinfection processes [1].

Conventional water treatment relies heavily on chemical coagulants such as alum (aluminium sulphate) and ferric salts. While effective, these chemicals introduce several concerns: potential health effects from aluminium residuals in treated water, generation of large volumes of non-biodegradable sludge, high procurement costs, and environmental contamination [2]. There is, therefore, a growing global interest in exploring sustainable alternatives, particularly bio-coagulants derived from natural plant sources.

Natural coagulants sourced from plants such as Moringa oleifera, Azadirachta indica (Neem), and Hibiscus esculentus (Okra) have demonstrated promising results in water treatment. These materials are biodegradable, non-toxic, locally available, and cost-effective. Their coagulating mechanisms include charge neutralisation of suspended particles and polymer bridging to form settleable flocs [3][4]. The effectiveness of such bio-coagulants has been validated through Jar Test experiments, which simulate the coagulation and flocculation processes under controlled laboratory conditions.

This study investigates the turbidity removal efficiency of Moringa, Neem, and Okra seed powders—individually and in blended combinations—applied to lake water collected from Chikkabanavara Lake, Bengaluru. The research aims to identify the most effective bio-coagulant combination and optimum dosage, contributing to the development of a practical and eco-friendly water treatment approach for rural and semi-urban communities.

II. LITERATURE REVIEW

Muthuraman [5] investigated Moringa oleifera, Strychnos potatorum, and Phaseolus vulgaris as low-cost coagulants through Jar Tests and found Moringa to produce clearer supernatant with faster-settling flocs, performing comparably to conventional alum at optimal doses. Jadhav [6] compared chitosan, Moringa seed powder, and cactus mucilage, identifying optimum concentrations of 1.5 mg/L, 80 mg/L, and 40 mg/L, respectively, with each acting via distinct mechanisms including charge neutralisation, protein-mediated adsorption, and viscosity-based bridging.

Desta et al. [7] demonstrated that Moringa seed powder effectively removed turbidity, colour, and COD from real wastewater, showing best performance at near-neutral pH. Asrafuzzaman et al. [8] tested Moringa oleifera, Cicer arietinum, and Dolichos lablab on artificially turbid water, recording up to 95.89% turbidity reduction with Cicer arietinum, alongside a measurable reduction in microbial load. Ndabigengesere et al. [9] isolated the cationic proteins in Moringa seeds responsible for charge neutralisation, achieving removal efficiencies exceeding 85% under optimal conditions.

Koul [10] reviewed natural coagulants across multiple plant, animal, and microbial sources, summarising removal efficiencies of 60–96% depending on material type, and underscoring the need for standardised extraction methods and scaling studies. Renault et al. [11] found chitosan to achieve turbidity removal above 90% with dense, fast-settling flocs and significantly lower sludge volumes than alum, while Choy et al. [12] evaluated banana peel and cassava starch extracts, noting 70–75% removal efficiencies and their suitability for low-resource, small-scale applications.

III. Methodology

A. MATERIALS PREPARATION

Three bio-coagulants were prepared for this study. Moringa oleifera leaves were thoroughly washed with distilled water, shade-dried at approximately 40°C in a laboratory oven to preserve heat-sensitive bioactive compounds, then ground using a mechanical grinder and sieved through a 0.075 mm mesh to achieve uniform particle size. Neem (Azadirachta indica) leaves were collected fresh, sun-dried for one week until they turned brown, then ground and passed through a 0.075 mm sieve to obtain fine powder. Okra (Hibiscus esculentus) seeds, procured commercially, were sun-dried for one week, ground to a dark-brown powder, and similarly sieved to approximately 0.075 mm particle size. All prepared powders were stored in sealed containers and used within 24 hours of preparation to prevent degradation of active compounds.

B. WATER SAMPLE COLLECTION

Turbid water samples were collected from Chikkabanavara Lake, Bengaluru, Karnataka (Lat. 13.080835° N, Long. 77.509225° E). A total of 20 litres of surface water was collected in two 10-litre clean containers. The initial turbidity of the collected sample was measured at 30.6 NTU and pH at approximately 7.1, representing moderately turbid raw water conditions.

C. Jar Test Procedure

The Jar Test was conducted to determine the optimum dosage of each bio-coagulant for maximum turbidity removal. Five 1000 mL beakers were filled with equal volumes of lake water. Bio-coagulant doses of 0 g (control blank), 0.05 g, 0.10 g, 0.15 g, and 0.20 g were added simultaneously to separate beakers. The procedure followed three stages: (i) rapid mixing at 100–120 rpm for 1–3 minutes to disperse the coagulant and destabilise colloidal particles; (ii) slow mixing at 20–35 rpm for 15–20 minutes to promote floc growth and particle aggregation into macroflocs; and (iii) quiescent settling for 30–60 minutes. After settling, the supernatant was carefully collected using a pipette from 1–2 cm below the surface and measured for residual turbidity (NTU) using a calibrated turbidimeter, and pH using a calibrated pH meter. The turbidity removal efficiency was calculated using:

$$\text{Turbidity Removal (\%)} = [(T_i - T_f) / T_i] \times 100$$

where Ti = initial turbidity (NTU) and Tf = final turbidity (NTU). This procedure was repeated for seven treatment configurations: three individual coagulants (Moringa, Neem, Okra), three binary blends (Moringa + Okra, Moringa + Neem, Neem + Okra in 50:50 proportions), and one ternary blend (Moringa + Okra at 50% each with Neem at 100%).

IV. Results and Discussion

A. INDIVIDUAL BIO-COAGULANTS

Table I presents the turbidity removal results for the three individual bio-coagulants. In all cases, the optimum dosage was 0.1 g/L, beyond which re-stabilisation of particles occurred, causing a decline in removal efficiency. Moringa powder achieved the highest individual removal of 37.9%, reducing turbidity from 30.6 NTU to 19 NTU. Neem and Okra seed powders both achieved 34.64% removal, reducing turbidity to 20 NTU at the same dosage. The slightly superior performance of Moringa is attributed to its well-documented cationic proteins that promote efficient charge neutralisation of suspended particles [9].

TABLE I

Turbidity Removal by Individual Bio-Coagulants (Initial Turbidity: 30.6 NTU)

Coagulant	Dose (g)	pH	Final Turbidity (NTU)	Removal (%)
Moringa	0.05	7.12	22	28.10
Moringa	0.10	7.04	19	37.90
Moringa	0.15	7.02	21	31.37
Moringa	0.20	7.00	25	18.30
Neem	0.05	7.18	27	11.76
Neem	0.10	7.13	20	34.64
Neem	0.15	7.06	24	21.56
Neem	0.20	6.98	26	15.03
Okra	0.05	7.16	25	18.30
Okra	0.10	7.11	20	34.64
Okra	0.15	7.04	24	21.56
Okra	0.20	7.02	26	15.03

B. BLENDED BIO-COAGULANT COMBINATIONS

The binary and ternary blends substantially outperformed individual coagulants in turbidity removal, as summarised in Table II. The Moringa + Okra (50:50) blend achieved 70.5% removal, reducing turbidity to 9 NTU at a 0.1 g dose. The synergistic effect is likely due to the complementary mechanisms of Moringa's protein-based charge neutralisation and Okra's polysaccharide-driven polymer bridging. The Neem + Okra blend achieved 67.32%, while Moringa + Neem achieved 60.78% at the same optimum dosage.

The highest turbidity removal of 73.85% was achieved by the ternary blend of Moringa (50%) + Okra (50%) + Neem (100%) at a dosage of 0.1 g, reducing turbidity from 30.6 NTU to just 8 NTU. This superior performance reflects the combined coagulation mechanisms: protein-mediated adsorption (Moringa), polysaccharide bridging (Okra), and the antimicrobial and charge-neutralising properties of Neem. All blends consistently showed that the optimum dosage was 0.1 g/L, and that overdosing beyond this threshold caused particle re-stabilisation and decreased performance.

TABLE II :Turbidity Removal by Blended Bio-Coagulants at Optimum Dosage (0.1 g/L)

Blend Combination	Proportion	Final Turbidity (NTU)	Removal (%)
Moringa + Okra	50:50	9	70.50
Moringa + Neem	50:50	12	60.78
Neem + Okra	50:50	10	67.32
Moringa + Okra + Neem	50:50:100	8	73.85

A comparison of all seven configurations at their respective optimum dosages (Fig. 1) clearly illustrates the progressive improvement in turbidity removal efficiency when bio-coagulants are used in combination. All pH readings remained within the near-neutral range (6.97–7.17), confirming that these bio-coagulants do not significantly alter the natural pH balance of treated water, which is an important criterion for potable water standards.

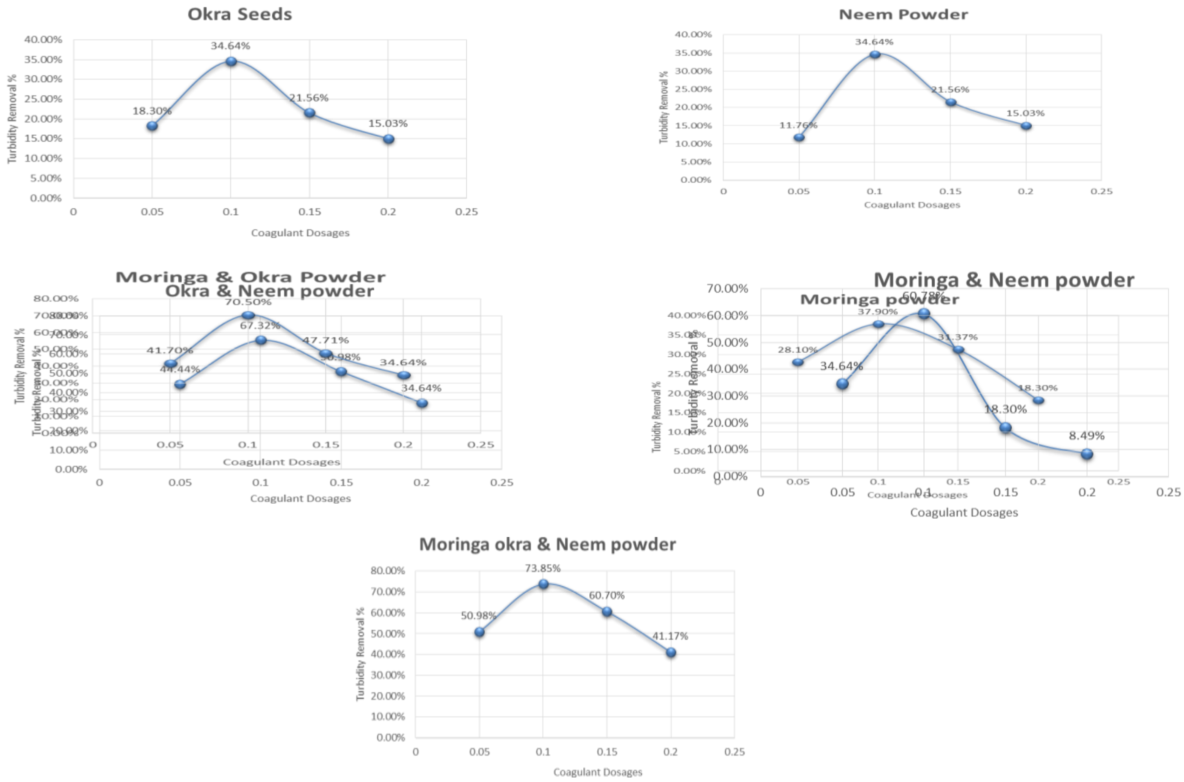

Fig. 1 Comparative turbidity removal efficiency of all bio-coagulant configurations at 0.1 g/L optimum dosage (see project report for graphs)

V. CONCLUSION

This study confirms that plant-derived bio-coagulants are viable, sustainable alternatives to conventional chemical coagulants for turbidity removal in lake water. The following conclusions are drawn from the experimental results:

All three individual bio-coagulants—Moringa, Neem, and Okra—demonstrated measurable turbidity removal, with Moringa achieving the best individual efficiency of 37.9% at an optimum dose of 0.1 g/L.

Blended combinations significantly outperformed individual coagulants due to synergistic coagulation mechanisms, with removal efficiencies ranging from 60.78% to 73.85%.

The ternary blend of Moringa + Okra + Neem (50:50:100) achieved the highest turbidity removal efficiency of 73.85%, reducing turbidity from 30.6 NTU to 8 NTU, and is recommended as the most effective treatment configuration.

The optimum dosage for all configurations was consistently 0.1 g/L. Overdosing beyond this level resulted in particle re-stabilisation and reduced removal efficiency.

All treated water samples maintained near-neutral pH (6.97–7.17), indicating that these bio-coagulants do not adversely affect the natural chemical balance of water.

These bio-coagulants are locally available, biodegradable, and low-cost, making them particularly suitable for rural and peri-urban water treatment systems where chemical coagulants are cost-prohibitive or unavailable.

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