EVALUATION OF CHICKPEA, RICE HUSK AND *MORINGA OLEIFERA* AS SUSTAINABLE ALTERNATIVES TO ALUM FOR TURBIDITY AND COLOR REMOVAL IN SURFACE WATER

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ABSTRACT

Access to safe and reliable drinking water remains one of the central challenges of this century, particularly in regions where conventional treatment methods are costly, limited in availability, or linked to environmental concerns. Alum, the most widely used chemical coagulant, has long been effective in turbidity and color removal. However, its heavy use raises issues such as residual aluminum in treated water and the generation of chemical sludge that is difficult to manage. These drawbacks have led to growing interest in natural, plant-based coagulants that are biodegradable, safer for health, and locally accessible. This study investigates the performance of *Cicer arietinum* (chickpea), rice husk, and *Moringa oleifera* as sustainable alternatives to alum for surface water treatment. Synthetic turbid water was prepared from raw samples collected at Dhanmondi Lake, Dhaka, standardized to 220 NTU turbidity and 305 Pt-Co color units. Jar tests were conducted with different dosages of each bio coagulant under rapid and slow mixing, followed by a 30-minute settling period. Efficiency was assessed through measurements of turbidity, color, and pH. Among the three natural coagulants, *Moringa oleifera* gave the strongest performance, reaching up to 93% turbidity removal and 90% color reduction at an optimum dose of 80 mg/L. Chickpea and rice husk also provided significant improvements, achieving turbidity reductions of 89% and 83% and color reductions of 86% and 79%. Alum remained slightly more efficient overall, with reductions of 98% and 94%, but the difference compared with *Moringa* was not substantial. All the natural coagulants kept pH stable, produced quick floc formation, and allowed effective settling within half an hour. Taken together, these outcomes show that natural coagulants can move beyond experimental trials and become practical tools in water treatment. *Moringa oleifera* in particular has the potential to provide results close to alum while avoiding its environmental and health drawbacks. The simplicity, low cost, and local availability of these materials make them well suited for communities where chemical treatments are either too expensive or raise long-term concerns. Future work that adapts these methods to larger treatment systems could help deliver safe and affordable water to a wider population.

Keywords: *Natural coagulants; Turbidity; Colour; Sustainable water treatment; Settling time*

1. INTRODUCTION

Access to clean and safe water is one of the biggest concerns of this century. In many regions, especially in developing countries, water from surface sources still carries high levels of suspended solids and organic impurities that make it unsafe for direct use. Conventional treatment methods mostly depend on chemical coagulants like aluminium sulphate (alum) to remove turbidity and color. Although alum has been a reliable coagulant for decades, its excessive use brings some serious drawbacks (Kawahara & Kato-Negishi, 2011). Traces of aluminium often remain in treated water, and the resulting chemical sludge poses handling and disposal problems. There is also growing awareness about the long-term environmental burden and rising cost of chemical treatment, which is why new and safer options are being explored.

During the last few years, natural and locally available coagulants have gained attention as substitutes for conventional chemicals. Materials of plant origin, such as seeds, husks, or pods, are renewable and biodegradable, and they can often be collected from agricultural waste (Asrafuzzaman et al., 2011). Using these as coagulants can reduce treatment cost and dependence on imported chemicals while producing less toxic sludge (Katayon et al., 2006). Among the plant materials studied so far, *Moringa oleifera* has shown the most consistent performance for turbidity and color removal (Taiwo et al., 2020). Other materials like chickpea (*Cicer arietinum*) and rice husk also contain active compounds that may help in the coagulation process, but their combined or comparative performance is still not well understood (Alazaiza et al., 2025). Since these are widely available in Bangladesh, they could serve as sustainable options for small-scale water treatment units, especially in rural and semi-urban communities.

In Bangladesh, surface water sources such as lakes, ponds, and rivers often have high turbidity and color because of erosion, runoff, and domestic discharge. Most studies so far have looked at single plant materials or have been carried out using water from other countries, making it difficult to judge how well these coagulants might work for local conditions (Tak et al., 2010). This research was undertaken to evaluate and compare the efficiency of *Cicer arietinum*, rice husk, and *Moringa oleifera* in removing turbidity and color from surface water collected from Dhaka. Jar-test experiments were conducted under controlled conditions to identify optimum dosages and assess how these natural materials perform compared with alum (Clark & Stephenson, 1999). The study also aims to highlight how these low-cost coagulants could support a more sustainable approach to water treatment in Bangladesh.

2. METHODOLOGY

2.1 Materials

Cicer arietinum (chickpea), rice husk, and *Moringa oleifera* seeds were procured from the local market in Dhaka, Bangladesh. Each material was carefully cleaned to remove impurities, sun-dried, and ground into a fine powder using a mechanical grinder. The powdered biocoagulants were stored in air-tight containers to maintain their quality and prevent contamination until further use.

2.2 Sample preparation

Raw water samples were collected from Dhanmondi Lake, a natural surface water body in Dhaka, Bangladesh. The collected water was used to prepare synthetic turbid water samples for the experiments. To achieve consistent and controlled turbidity, a measured quantity of locally sourced mud was mixed with the raw water and stirred thoroughly (Taiwo et al., 2020). The synthetic water samples were standardized to an initial turbidity of 220 NTU, a color intensity of 305 Pt-Co units, and a pH of 7.27

2.3 Experimental Procedure

Jar tests were performed to evaluate the coagulation efficiency of the biocoagulants and determine their optimum dosages. Each experiment was conducted using twelve 1-liter beakers, filled with 1 liter of synthetic water sample.
The jar test procedure involved two types of mixing speed:

1. Rapid Mixing: A high-speed mixing stage at 250 rpm for 1 minute followed by 40 rpm for 15 minutes to ensure uniform dispersion of the biocoagulant in the water sample (Asrafuzzaman et al., 2011).
2. Slow Mixing: A low-speed mixing phase at 45 rpm for 1 minutes, followed by gentle mixing at 25 rpm for 15 minute to facilitate floc formation.

After the mixing phases, the samples were left undisturbed for a settling period of 30 minutes to allow the flocs to sediment. Post-settling, the supernatant water was carefully sampled to measure the final turbidity, color, and pH. The turbidity and color removal efficiencies were calculated based on the differences between initial and final values.

2.4 Analytical Methods

The performance of each coagulant was evaluated by measuring turbidity, color, and pH before and after treatment. Turbidity was measured using a digital nephelometric turbidimeter, color was determined using a spectrophotometer at 455 nm wavelength, and pH was recorded with a calibrated digital pH meter. Each test was repeated three times, and the average values were used for analysis to reduce experimental error.

The removal efficiency of turbidity and color was calculated using the following equation:

$$\text{Removal Efficiency (\%)} = \frac{C_i - C_f}{Ci} \times 100$$

where C_i and C_f represent the initial and final concentrations (NTU or Pt-Co units) of the sample.

The optimum coagulant dose was identified as the lowest concentration that achieved the highest removal efficiency while maintaining acceptable pH stability.

3. RESULTS AND DISCUSSION

The coagulation performance of *Cicer arietinum* (chickpea), rice husk, and *Moringa oleifera* was assessed in terms of turbidity and color removal under different operating conditions. Tables 1 and 2 present the detailed experimental data obtained from rapid mixing, while Figures 1(a–d) illustrate the overall trend of turbidity and color removal compared to alum.

In all cases, the natural coagulants demonstrated a clear dose–response relationship: turbidity and color removal increased with dosage up to an optimum point and then declined slightly at higher concentrations. This behavior is typical of the coagulation process, where increasing the coagulant dose enhances particle destabilization through charge neutralization until excess coagulant leads to restabilization or re-dispersion of particles. The data show that all three natural coagulants achieved considerable reductions in turbidity and color, although their efficiency and optimum dosage differed depending on their composition.

Among the tested materials, *Moringa oleifera* consistently achieved the best results, removing about 93% of turbidity and 90% of color at an optimum dose of 80 mg/L. The effectiveness of *Moringa oleifera* can be attributed to its high content of water-soluble, positively charged proteins, which interact with negatively charged colloidal particles, leading to rapid floc formation and effective settling. Chickpea also showed promising performance, reaching 89% turbidity and 86% color reduction at 100 mg/L, while rice husk achieved its best performance at 500 mg/L with 83% and 79% reductions, respectively. The higher required dose for rice husk is likely related to its relatively low content of active cationic compounds and more fibrous, cellulose-based structure, which promotes physical adsorption but contributes less to charge neutralization.

Table 1: Experimental data for rapid mixing (250 rotation per minute for 1 minute and after those 40 rotations per minute for 15 minutes)

Coagulants	Jar No.	Dose (mg/L)	Final pH	Final Turbidity (NTU)	Final Color (Pt-Co unit)	Percentage of Turbidity reduction (%)	Percentage of Color reduction (%)
Chickpea	1	15	7.07	99.1	160	55	48
	2	30	7.23	68	126	69	59
	3	45	7.29	45.4	91	79	70
	4	60	7.27	52.3	95	76	69
	5	75	7.29	46.4	53	79	83
	6	90	7.18	29	44	87	86
	7	100	7.32	24.1	42	89	86
	8	200	7.33	44.2	83	80	73
	9	300	7.42	63.8	156	71	49
	10	400	7.37	67.4	212	69	30
	11	500	7.41	66.2	157	70	49
	12	600	7.34	88	178	60	42
Rice Husk	1	50	7.09	81.4	157	63	49
	2	100	7.13	76.9	151	65	50
	3	150	7.15	64.5	147	71	52
	4	200	7.16	69.6	143	68	53
	5	300	7.25	54.8	120	75	60
	6	400	7.3	49.6	113	77	63
	7	450	7.31	43.1	67	80	78
	8	500	7.35	37.5	64	83	79
	9	600	7.36	49.2	68	78	78
	10	700	7.38	53.1	114	76	62
	11	800	7.4	62.4	124	72	59
	12	900	7.41	123	163	44	47
Moringa oleifera	1	20	7.11	110	99	50	68
	2	30	7.29	65.9	85	70	72
	3	50	7.22	36.7	52	83	83
	4	70	7.18	18.1	38	92	88
	5	80	7.05	15	32	93	90
	6	90	7.05	18.3	62	92	80
	7	100	7.02	24.2	61	89	80
	8	150	7.26	50.6	87	77	71
	9	200	7.18	96.5	121	56	60
	10	300	7.21	91.4	124	58	59
	11	400	7.01	105.3	148	52	51
	12	500	7.29	119.8	179	46	41

Table 2 provides a direct comparison of the natural coagulants with alum, the conventional reference coagulant. Alum remained the most efficient overall, achieving 98% turbidity and 94% color removal, but the difference between alum and *Moringa oleifera* was modest. This finding reinforces that plant-based materials, particularly *Moringa oleifera*, can deliver comparable treatment outcomes while avoiding residual aluminum contamination and reducing sludge toxicity. Another important observation is that the pH of treated water remained nearly neutral (7.0–7.4) for all natural coagulants, indicating that they do not significantly alter water chemistry. This stability makes them especially suitable for decentralized systems, where post-treatment pH correction is impractical.

The graphical results in Figure 1 further support these observations. The curves show that turbidity and color removal increased steadily with dosage until reaching the optimum, followed by a mild drop at higher concentrations. *Moringa oleifera* achieved the steepest removal curve, while chickpea and rice husk displayed broader, flatter curves that indicate lower activity but more tolerance to dose variation. The formation of dense and rapidly settling flocs during the *Moringa oleifera* tests was visually noticeable, confirming the material's high coagulation potential.

Table 2: Comparison of the performance of natural coagulants with alum

Coagulants	Final turbidity (NTU) at optimum dose	Final Color (Pt-Co unit) at optimum dose	Highest Percentage of Turbidity reduction (%)	Highest Percentage of Color reduction (%)
Chickpea	24.1	42	89	86
Rice Husk	37.5	64	83	79
Moringa oleifera	15	32	93	90
Alum	4.4	18	98	94

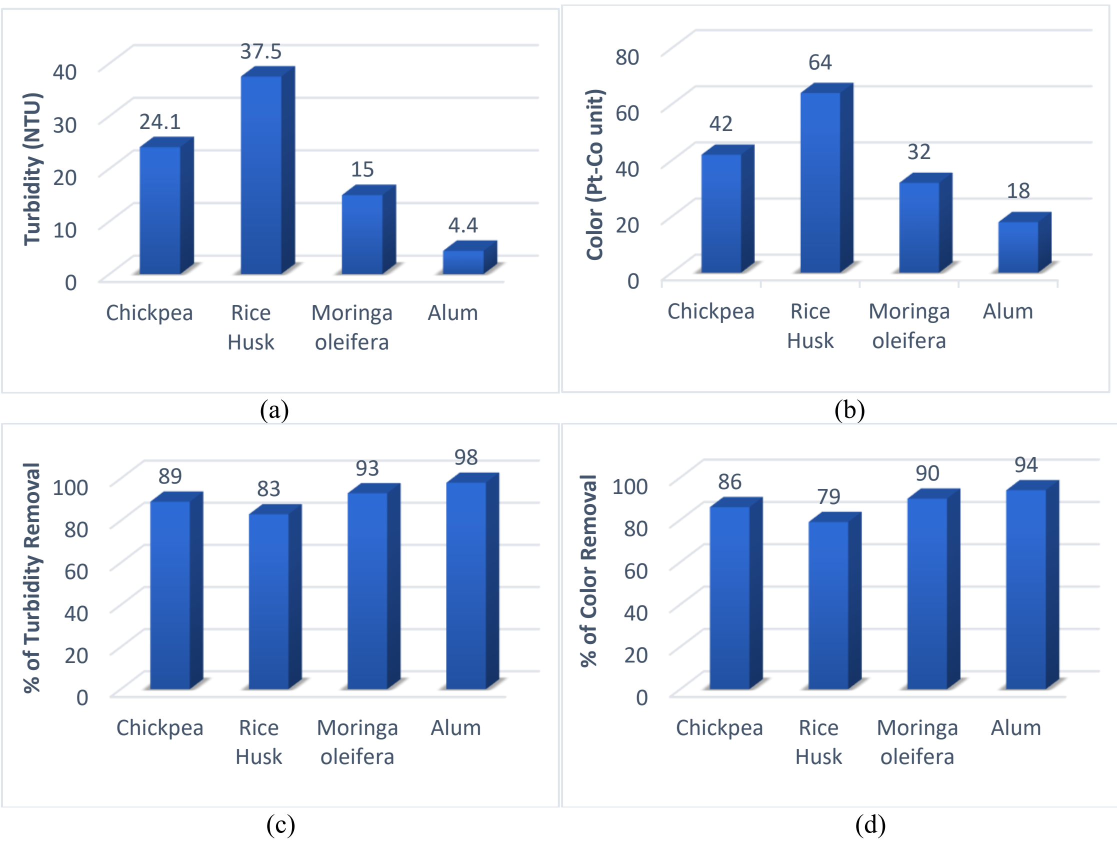
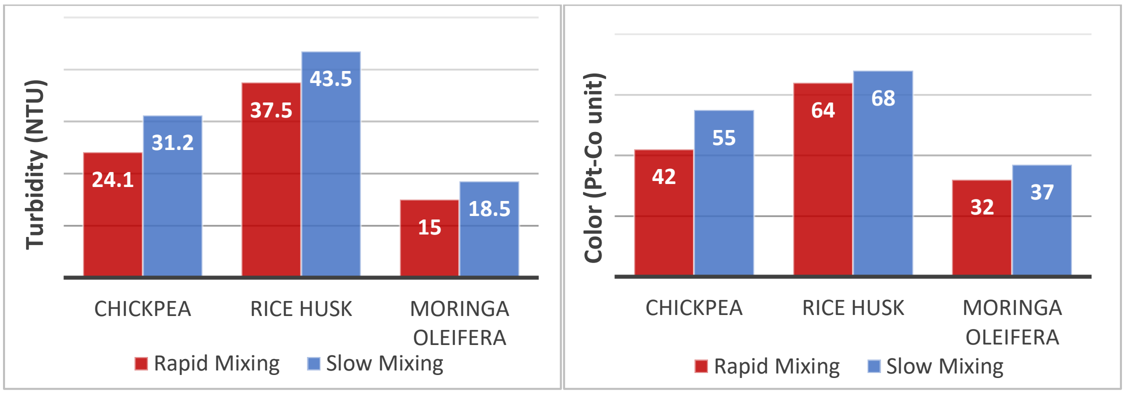


Figure 1: Comparison of the performance of the natural coagulants with alum in terms of turbidity and color removal

A comparison between rapid and slow mixing conditions is summarized in Table 3 and Figure 2. Removal efficiencies under rapid mixing were slightly higher for all coagulants than under slow mixing. For example, *Moringa oleifera* achieved 93% turbidity removal under rapid mixing compared to 90% under slow mixing. Chickpea and rice husk showed similar trends, with decreases of about 3–5% when mixing intensity was reduced. This difference may be attributed to the better dispersion and particle–coagulant contact achieved during rapid mixing, which enhances floc nucleation and aggregation. However, excessively vigorous mixing can also break flocs once formed; therefore, the chosen combination of 250 rpm for 1 min followed by 40 rpm for 15 min appeared to provide an optimal balance between floc growth and stability.

Table 3: Comparison data of Turbidity and Color for rapid mixing and slow mixing

Coagulants	Turbidity (NTU)		Color (Pt-Co unit)	
	Rapid	Slow	Rapid	Slow
Chickpea	24.1	31.2	42	55
Rice Husk	37.5	43.5	64	68
Moringa oleifera	15	18.5	32	37



(a) (b)

Figure 2: (a) Turbidity (NTU) and (b) Color (Pt-Co unit) at optimum dose for rapid and slow mixing

The influence of settling time was also examined to understand floc compactness and sedimentation behavior (Table 4, Figure 4). Turbidity decreased gradually with longer settling periods, but most of the removal occurred within the first 30 minutes. After that, further reductions were minor, suggesting that the flocs produced by the natural coagulants were relatively dense and settled rapidly. For instance, turbidity for *Moringa oleifera* dropped from 15 NTU after 30 minutes to 14 NTU after 120 minutes, indicating that extending the settling time beyond 30 minutes yields limited improvement. This observation is advantageous for practical application since shorter settling times can reduce treatment tank volumes and operational costs.

Table 4: Turbidity (NTU) at Different Settling Time

Coagulants	Turbidity (NTU) at Different Settling Time			
	30 minutes	60 minutes	90 minutes	120 minutes
Chickpea	24.1	23.3	22.8	22.4
Rice Husk	37.5	37	36.9	36.4
Moringa oleifera	15	14.4	14.2	14

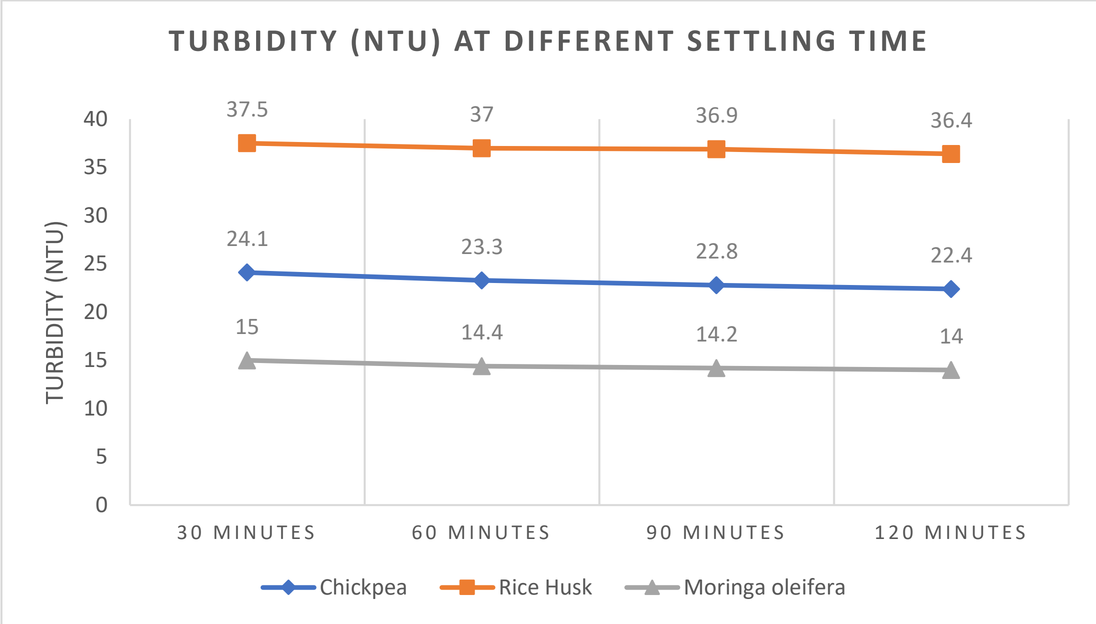


Figure 4: Turbidity (NTU) at different settling time

The performance of the three plant materials is closely tied to what they are made of. In the case of *Moringa oleifera*, the seed contains water-soluble proteins that carry a positive charge, and these proteins help pull together the negatively charged particles that cause turbidity. Because of this, Moringa reacted quickly with the suspended particles and formed compact flocs within a short time. Chickpea also contains proteins and some polysaccharides that can interact with particles in the water. However, the strength of this interaction appears to be slightly weaker than Moringa, which explains why chickpea needed a bit more dosage to reach its best performance. Rice husk behaved quite differently. It is mainly composed of silica and fibrous materials, so most of its action came from adsorption and bridging rather than charge neutralization. This also explains why it required much larger doses to achieve similar reductions in turbidity and color.

The overall trends seen in this study are consistent with what other researchers have reported, especially regarding the strong performance of Moringa and the moderate results from chickpea. What makes the present work useful is that all three materials were tested under the same conditions with surface water collected from Dhaka. This provides a clearer picture of how these coagulants behave when applied to local water sources, something that many earlier studies did not focus on.

Looking at the results from a practical angle, Moringa has the potential to be used on its own or to reduce the amount of alum needed in a combined treatment approach. Chickpea and rice husk may not be as strong as Moringa, but they can still play a role in places where Moringa is not widely available. Their ability to work without altering the pH of the water, along with the fact that they are biodegradable, makes them easier to manage after treatment.

In general, the results match well with what small or community-level treatment systems need. These natural materials are inexpensive, easy to obtain and do not leave behind harmful residues. If used properly, they can support a more sustainable approach to water treatment in Bangladesh and other similar regions where access to chemicals is limited or costly.

4. CONCLUSION

A key aim of this study was to understand whether three easily available materials, chickpea (*Cicer arietinum*), rice husk and *Moringa oleifera*, could realistically serve as substitutes for alum in surface-water treatment. From the jar tests, it was clear that all three were able to lower turbidity and color, although their performance was not equal. Among the natural options, *Moringa oleifera* showed the most consistent improvement, and at its best dose its results came close to what was achieved with alum. Chickpea and rice husk also performed well, but they needed comparatively higher dosages to reach their optimum points.

One encouraging observation was that none of the natural coagulants caused any meaningful shift in pH. This is helpful for situations where water is treated in small or decentralized facilities that cannot afford additional pH control steps. Another practical advantage was the speed at which flocs formed and settled, especially with *Moringa oleifera*, which makes it suitable for settings where long settling times are difficult to maintain.

Beyond the numbers, the larger takeaway from this study is the possibility of reducing dependence on chemical coagulants by making use of materials that are already present in local communities. Using these natural sources can lower treatment costs, cut down on alum-related sludge, and create opportunities to reuse agricultural by-products instead of letting them go to waste. While *Moringa oleifera* proved to be the strongest candidate overall, chickpea and rice husk still hold value in areas where Moringa is not widely grown or available.

Further research should explore how these findings translate outside the laboratory. Testing the coagulants in pilot or field units, checking how they perform over longer periods, and studying how they can be stored and prepared in real communities will provide a clearer picture of their practical usefulness. Exploring combinations of natural and small amounts of chemical coagulants may also open new possibilities. With continued work, these plant-based materials could become a realistic option for improving access to safe and affordable drinking water in many regions.

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DECLARATION OF USE OF AI

During the preparation of this manuscript, the authors used generative AI tools only as supportive writing aids, mainly for improving grammar, reorganizing sentences, and checking the clarity of expression. All technical ideas, experimental methods, data analyses, and interpretations were developed entirely by the authors. The authors carefully reviewed, edited, and verified all text generated or suggested by AI tools to ensure accuracy and suitability for academic publication. No AI tools were used to produce, process, or analyze any part of the research data. The authors take full responsibility for the content of this work.

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