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Tablet-based application of *Moringa oleifera* seed powder for household turbidity reduction: Experimental study and prototype development

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ABSTRACT

The increasing demand for safe drinking water and the growing environmental concerns associated with chemical coagulants have spurred the exploration of sustainable alternatives for water treatment. This study investigated the effectiveness of *Moringa oleifera* seed powder as a natural coagulant for turbidity removal and proposed a tablet-based dosing approach suitable for household-scale applications. Jar test experiments were conducted using varying dosages to determine the optimal coagulant concentration for different turbidity levels. To enhance practical usability, standardized 1 g tablets were developed for simple and controlled dosing. The results show turbidity removal efficiencies of up to 88.9%, reducing turbidity to permissible limits of IS 10500:2012 (1–5 NTU). A compact prototype integrated with a turbidity sensor was also developed to provide real-time measurement and dosage recommendation in the form of tablets. A correlation between initial turbidity and tablet dosage was established. The findings demonstrated that tablet-based Moringa oleifera coagulation can provide an effective, low-cost, and environmentally sustainable alternative to conventional alum-based treatment for household and rural water purification systems.

Keywords: turbidity reduction, *Moringa oleifera*, unit-gram tablets, coagulation-flocculation, jar test.

INTRODUCTION

The access to safe drinking water remains a global challenge, particularly in rural and resource-limited regions. High turbidity not only affects the aesthetic quality of water but also reduces disinfection efficiency by shielding microorganisms (Rasheed, 2023). Conventional coagulation–flocculation using chemical coagulants such as alum is widely practiced; however, it has several limitations, including sludge generation, potential health concerns, and operational costs. Natural coagulants have recently gained attention as sustainable alternatives. *Moringa oleifera* seeds contain cationic proteins that promote particle destabilization and floc formation (Nisha, 2017). Using *Moringa oleifera* seed powder as a natural coagulant may release minor amounts of dissolved organic matter into treated water, due to its biodegradable, protein-based nature. Previous studies show that with optimized dosage, organic additions are minimal, posing no significant water quality risks. Conversely, using *Moringa oleifera* for coagulation and flocculation effectively eliminates suspended matter, turbidity, and colloids, leading to an overall enhancement in water quality. Although practical implementation at the household level remains limited due to challenges in dosage control and user handling.

This study bridged this gap by introducing a tablet-based dosing system integrating with turbidity monitoring unit and user-friendly water treatment.

This research introduced a standardized tablet-based formulation of *Moringa oleifera* for precise household dosing and integrated it with a real-time turbidity sensing system. It also established a quantitative relationship between initial turbidity and required dosage, bridging the gap between laboratory research and practical application.

OBJECTIVES

1. To analyze turbidity reduction efficiency using *Moringa oleifera tablets.*
2. To determine optimum dosage for effective water treatment.
3. To develop standardized unit dose tablets for consistent application.
4. To establish correlation between initial turbidity and required tablet dosage.
5. To evaluate tablet performance across varying turbidity ranges.

METHODOLOGY

Although previous studies proved that *Moringa oleifera* seed powder effectively reduce turbidity, yet its practical implementation at the household and rural level remains limited. This study aimed to establish standardized, unit-dose *Moringa oleifera* tablets to facilitate decentralized water treatment. Unlike previous laboratory-based approaches requiring loose powder or extracts, this study introduced a user-friendly unit-gram tablet that allows users to dose accurately without any technical expertise.

Additionally, systematic jar tests were used to determine the quantitative relationship between initial turbidity and ideal moringa oleifera dosage. This feature calculates the required tablets dosages across diverse turbidity ranges while ensuring key water quality parameters – specially pH, alkalinity, and hardness within safe limits. This improved, practical methodology standardized dosage, and performance testing constitutes a practical improvement over existing methods.

This research transitions laboratory findings into practical usage by transforming a natural seeds-based coagulant into a low-cost, eco-friendly, and scalable tablet form. This study provides a sustainable water treatment solution for rural and underserved communities, ensuring safe consumption by reducing turbidity without dependence on conventional chemical coagulants. Although the tablet-based system effectively lowers turbidity via coagulation–flocculation, it is not a standalone solution for complete water purification. To enhances effectiveness, the proposed design incorporates a multi-barrier framework involving complimentary disinfection and filtration processes.

Materials

Dried *Moringa oleifera* seeds were procured, cleaned, and pulverized into a fine powder. To ensure uniform and reproducible dosing, the powder was formulated into unit gram tablets utilizing a lab scale compression machine. Prior to analysis, surface water samples with varying turbidity levels were obtained from a local source and kept in clean polyethylene containers. Standard methods were employed to establish baseline water quality, focusing on turbidity, pH, alkalinity and hardness.

Preparation of tablets

The *Moringa oleifera* seeds were cleaned, dried, and pulverized into fine powder. The powder was sieved and compressed into uniform tablets using a laboratory tablet press. Tablets were stored in airtight containers to prevent moisture absorption. On the basis of study findings and consistent performance, the tablets are expected to remain effective for four months, provided they are stored correctly. Proper storage is crucial to maintain this efficacy. The 1 g tablet offers a simple, standardized dose that is easy to handle and apply without specialized measuring tools. This is especially useful for home-based use in under-resourced areas. The tablet size provides flexible dosing, allowing for adjustments based on raw water turbidity. For safe drinking water, use these tablets for initial treatment, but follow up with filtration and disinfection to ensure they meet quality standards (Figure 1).

Water sample collection

Surface water samples with varying turbidity levels were collected and stored in clean polyethylene containers. Initial parameters such as turbidity, pH, alkalinity, and hardness were measured.

Jar test procedure

Jar tests were conducted to determine optimal dosage. Rapid mixing was performed at 100 rpm for 1 minute, followed by slow mixing at 20 rpm for 20 minutes. The samples were allowed to settle for 60 minutes before analysis.

All experiments were performed in triplicate, and results were reported as mean values.

Figure 1. *Moringa oleifera* tablets

Analytical methods and performance evaluation

The final turbidity of the treated samples was measured with a nephelometric turbidity meter, and reduction efficiency was determined using:

$$\textit{Removal efficiency (\%)} = \frac{T_i - T_f}{T_i} \times 100 \quad (1)$$

where: T_i and T_f represent initial and final turbidity in NTU, respectively.

Additionally, to ensure that the application of *Moringa oleifera* tablets did not adversely affect water quality variations in pH, alkalinity, and hardness before and after treatment were monitored. To improve reliability, results was ensured by running all experiments in triplicate, and reporting average. All experiments were conducted in triplicate, and results are presented as mean values. Experimental variation was observed within ±5%, indicating good reliability.

Optimization approach

A 15 L laboratory model was created to assess the effectiveness of *Moringa oleifera* tablets and to define the correlations between initial turbidity and optimum dose required. The tablet count for effective treatment was established by ensuring turbidity reduction within acceptable drinking regulations. With this method, the formulated tablets can be readily applied for decentralized and household-level water treatment.

Design and key features of the proposed treatment model

The developed prototype consists of a 15 L treatment tank equipped with a turbidity sensor, control unit, and mechanical mixing system. The system measures initial turbidity and recommends the required number of tablets through a digital interface. The integrated mixing mechanism ensures uniform dispersion of the coagulant, followed by sedimentation and collection of treated water. This design simplifies operation and minimizes dosing errors, making it suitable for household-level applications.

Experimental operation of the proposed model

The experimental operation of the proposed treatment model was carried out using a turbidity reduction unit with an effective tank capacity of 15 L. Initially, the tank was filled with raw turbid water collected from the natural water source. The initial turbidity of the water sample was measured by use of integrated digital turbidity (TDS-based) sensor. Precision in the proposed dosing system is largely contingent upon the calibration and sensitivity level of the turbidity sensor. The sensor employed has a 0–100 NTU operating range with a measurement resolution of roughly ±1 NTU. Variations in measurement may occur due to fluctuations in raw water characteristics, sensor response limitations, and hydraulic mixing conditions. The indicated turbidity was entered into the tablet indicator keypad, and the control module processed the input. The dedicated digital display first confirmed the entered initial turbidity and subsequently the system displayed the number of tablets needed for coagulation and flocculation on the programmed turbidity ranges (e.g., 1–10 NTU, 10–20 NTU, etc.). The recommended tablets were introduced into the tank. A motor-driven mixing unit installed on the tank lid was then activated to ensure uniform dispersion of the *Moringa oleifera* tablets in the water. The mixing process was maintained for approximately 5–10 min to promote particle destabilization and floc formation.

After mixing, the water was allowed to remain undisturbed for a detention period of about 1 h to promote gravitational settling of suspended particles and formed flocs. The clarified water was withdrawn through the treated-water outlet tap without disturbing the sludge layer. Ultimately, the accumulated sludge was removed via bottom outlet to the collection tank. The sediment produced mainly comprises suspended particles clustered together by natural coagulant agents from *Moringa oleifera*. Due to its biodegradable and non-toxic nature, the sludge presents minimal environmental risk compared to that generated from conventional chemical coagulants. The proposed system efficiently removes turbidity at house hold scale by turbidity sensing, dosage control, mixing, and sedimentation into a single treatment cycle by using the *Moringa oleifera* tablets (Figure 2).

RESULTS AND DISCUSSION

Table 1 and Figure 3 outlines the linkage between initial turbidity levels, ideal dose of *Moringa oleifera*, resultant water clarity, and the amount of tablets required for treating 15 L of water. The data demonstrate direct correlation between initial turbidity and required dose, for low turbid water (0–50 NTU), an optimum dose of 0.6 mg/L was sufficient to reduce turbidity to 9 NTU roughly equivalent to one tablet. At 83 NTU, the required dose 0.76 mg/L to bring turbidity of 7 NTU, which consumes up to 1.5 tablets.

The optimal dosage was found to be 0.9 mg/L for 100-150 NTU and 1.03 mg/L for 150–200. At these dosages, turbidity was reduced to 5–6 NTU, closely approaching the maximum permissible drinking water standards recommended by WHO and IS 10500. The number of tablets required for highest turbidity level increased around two. This demonstrates that the formulated tablet system can be effectively scaled according to raw water quality, making it suitable for household and rural application.

The increasing trend of tablet requirement with turbidity confirms the importance of dosage optimization when using natural coagulants to avoid under- or over-dosing. Overdosing with the *Moringa oleifera* tablets can degrade water quality by raising residual organic matter levels. Furthermore, this over-dosing can cause stabilized particles to scatter again, breaking apart accumulated flocs, which reduces the overall efficiency of the flocculation process. Consequently, determining the optimum dose is necessary for efficient

Figure 2. Turbidity reduction system (model)

Table 1. Turbidity-based tablet dosage requirement

Sr. No.	Turbidity ranges (NTU)	Initial turbidity (NTU)	Optimum dose (mg/L)	Final turbidity (NTU)	Dose for 15 lit. (mg/L)	Number of tablets
1	0 – 50	48	0.6	9	120	1
2	50 – 100	83	0.76	7	134	1.5
3	100 – 150	110	0.9	5	140	1.5
4	150 – 200	173	1.03	6	170	2

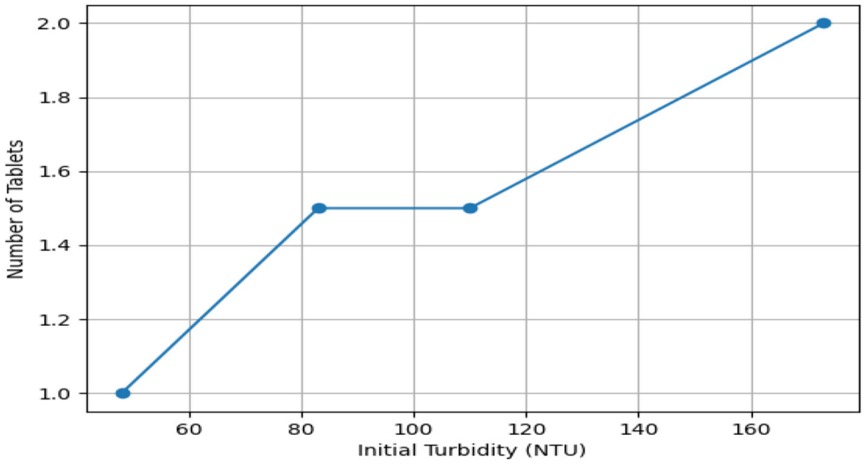

Figure 3. Initial turbidity vs required tablets

suspended particle removal while protecting the overall quality of the treated water

Table 2 clarifies that the effect of *Moringa oleifera* dosage on turbidity reduction for an initial turbidity of 54 NTU. As the dosage increased from 10 to 50 mg/L, the final turbidity decreased significantly from 15 NTU to 6 NTU. The results of higher coagulant dosage indicated improved effective destabilization and aggregation of suspended particles.

At reduced dosage of 10 mg/L, turbidity reduction efficiency was 77.78%. Increasing the dosage to 20 mg/L improved efficiency to 81.48%, while 30 mg/L achieved 83.33% removal. Further increases to 40 and 50 mg/L resulted in efficiencies of 85.18% and 88.88%, respectively. These findings are consistent with recent studies on plant-based coagulants, which report enhanced particle aggregation due to charge neutralization and polymer bridging mechanisms (Figure 4).

However, although efficiency increased continuously, the improvement beyond 40 mg/L became marginal, suggesting the presence of an optimum dosage range. Overdosing may offer little extra removal benefits and may introduce organic contaminants into treated water. Consequently, applying 30–40 mg/L coagulant is recommended to effective turbidity removal while keeping economic efficiency (Figure 5).

Table 3 compares turbidity reduction efficiencies of conventional alum and the *Moringa oleifera* tablets using wide coagulant dosages for an initial turbidity of 54 NTU. As dosage increased, both coagulants exhibit higher removal

Table 2. Turbidity reduction efficiency

Sr. No.	Dosage of coagulant (mg/L)	Initial turbidity (NTU)	Final turbidity (NTU)	Efficiency
1	10	54	15	77.78%
2	20	54	13	81.48%
3	30	54	9	83.33%
4	40	54	8	85.18%
5	50	54	6	88.88%

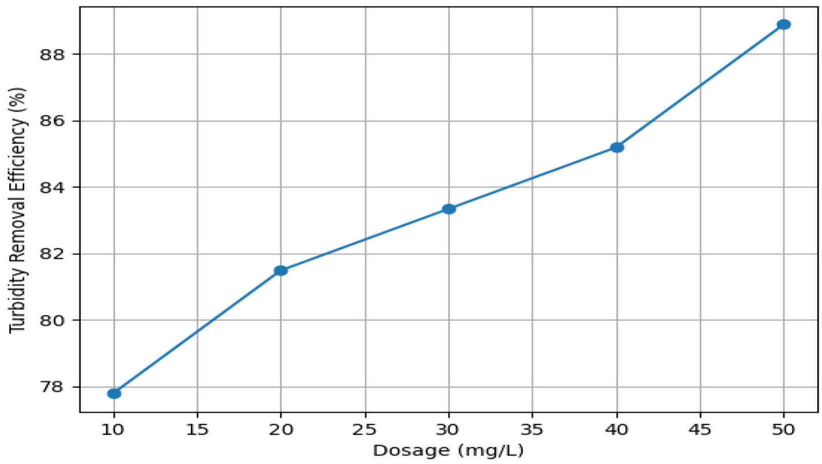

Figure 4. Effect of coagulant dosage on turbidity removal efficiency

efficiencies, confirming successful particle aggregation and sedimentation. Ordinary alum demonstrated improved clarification performance at higher concentrations; increasing the dose from to 10 mg/L to 50 mg/L enhanced the reduction rate by over 16% reaching a low of 6 NTU. The consistent improvement indicates that the coagulant concentration increases, hydrolyzed aluminium species enhance floc formation through progressive charge neutralization. As results plateaued between 40 and 50 mg/L – improving only from 85.19% to 88.89% – this suggests an optimal dosage range was reached, and higher concentrations would provide little added benefit. Conversely, the *Moringa oleifera* tablets showed better effectiveness across nearly all tested dosages. *Moringa oleifera* achieved an efficiency of 79.63% at 10 mg/L, which perform better than alum by approximately 7.4%. A significant improvement occurred at dose 20 mg/L, reducing turbidity from 54 NTU to 4 NTU, this represents 92.59% removal efficiency, significantly out performing alum which only achieved 75.93% at same dose. This enhanced result shows that cationic proteins present in *Moringa oleifera* that drive particle bridging and speed up flocculation.

High dose of the *Moringa oleifera* tablets performed exceptionally well yielding results 88.89%, 90.74%, and 94.44% at 30, 40, and 50 mg/L, respectively. The water treatment process achieved its peak efficiency of 94.44% at 50 mg/L, producing water with 3 NTU turbidity meeting WHO and IS 10500 standards (<5 NTU). At

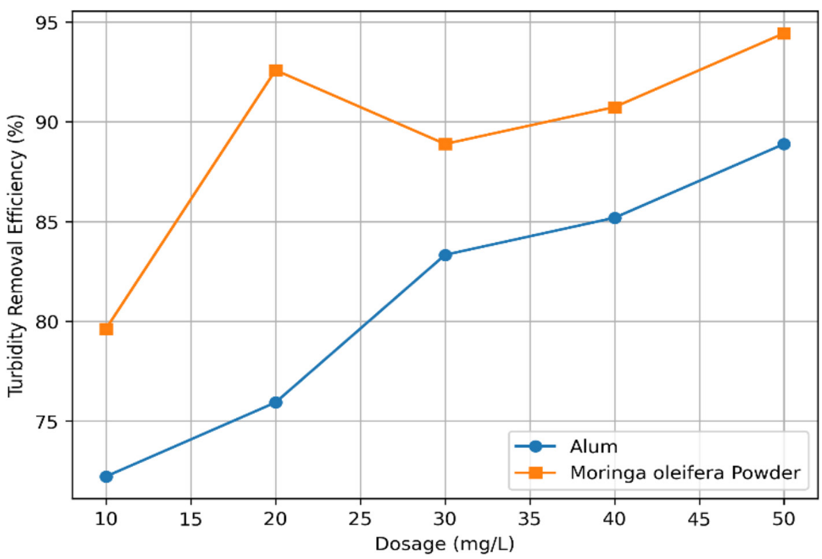

Figure 5. Performance comparison of *Moringa oleifera* and alum in reducing turbidity

Table 3. Performance comparison of *Moringa oleifera* and alum in reducing turbidity

Coagulant	Dosage (mg/L)	Initial turbidity (NTU)	Final turbidity (NTU)	Removal efficiency (%)
Alum	10	54	15	72.22
Alum	20	54	13	75.93
Alum	30	54	9	83.33
Alum	40	54	8	85.19
Alum	50	54	6	88.89
Moringa Powder	10	54	11	79.63
Moringa Powder	20	54	4	82.59
Moringa Powder	30	54	6	88.89
Moringa Powder	40	54	5	90.74
Moringa Powder	50	54	3	94.44

equal dosage, *Moringa oleifera* exhibited better than coagulation performance than conventional alum, achieving 50% residual turbidity (3 NTU vs 6 NTU). *Moringa oleifera* act as superior coagulant to ordinary alum, delivering greater than 90% efficiency at just 20 mg/L whereas standard alum requires 50 mg/L to reach 88.89% effectiveness. The high effectiveness of low dose Moringa oleifera improves the economic and operational viability of decentralized water treatment.

Essentially, regular alum works by reacting with water (mainly through hydrolysis) to form aluminium hydroxide precipitates, which then trap suspended particles through sweep flocculation. In contrast, *Moringa oleifera* contents has water-soluble, positively charged (cationic) proteins that act as a natural coagulant. These proteins work by neutralization of suspended particles and acting as polymer bridge to form floc formation at lower dosages. This difference highlights moderate application-level yields superior performance for *Moringa oleifera*. Apart from high efficiency turbidity reduction, the use of *Moringa oleifera* offers superior environmental and public health benefits compared to chemical coagulants, eliminates the risk of residual alum in treated water and produce biodegradable sludge. These attributes, alongside superior coagulation performance in reduction in turbidity, support the suitability of *Moringa oleifera* as an environmentally conscious, alternative for household and rural water treatment applications.

Performance analysis of the proposed tablet system

Figure 4 illustrates that higher dosage reduces the turbidity from an initial turbidity of 54 NTU, as stronger particle destabilization and floc formation improve reduction efficiency. The direct correlation between initial turbidity and required number of tablets, non-technical users can determine the correct dose based on a simple turbidity measurement. To ensure water safety, the system effectively lowers turbidity through a synchronized process of monitoring, doses adjustments, and mechanical agitation.

CONCLUSIONS

The findings indicate that the tablet-form of *Moringa oleifera* seed powder serves as an effective natural bio coagulant for treating turbidity at household level. The developed tablets achieve a significant 78–89% reduction in turbidity, bringing treated water close to WHO standards of 5 NTU under optimum dosing conditions. The results established an accurate pairing between initial turbidity and specific tablet dosage, enabling controlled, reproducible treatment that requires no special expertise. This all-in one, easy-to use unit handles turbidity checks, dosing, mixing, and sediment removal, making ideal for decentralized water treatment. Utilizing *Moringa oleifera* tablets offers sustainable, cost effective, and practical alternative to conventional chemical coagulants, providing a practical solution for producing safe drinking water quality.

The study was limited to laboratory-scale evaluation and does not include extensive field validation. Additionally, only turbidity removal was analyzed, while parameters such as microbial contamination, organic matter, and heavy metals were not investigated. Further research is required to assess long-term water quality and storage stability.

Validating the *Moringa oleifera* tablets in broad field trials is necessary to improve their scalability. Further research is recommended to thoroughly conduct test on tablets disinfection interactions, microbial inactivation potential and overall efficiency for removal of pathogens. Optimization of tablet formulation for faster dissolution can further improve their usability. Integration of the system with low-cost filtration and disinfection units would provide a complete household treatment solution. Additionally, socio-economic assessment and community-based trials are suggested to evaluate user acceptance and operational feasibility in rural and resource-limited settings.

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