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Efficacy of Moringa oleifera Seed Powder as a Natural Coagulant in Improving pH, Turbidity, and Total Suspended Solids of Surface Water from the Galian C Area, Banawa District, Donggala Regency

Aldiansa[1*], Mery Napitupulu[2], Ratman[3]
Tadulako University
Corresponding Author: Aldiansa aldiansakaryanto@gmail.com

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A B S T R A C T

This research evaluated the capacity of Moringa oleifera seed powder to enhance the physical quality of surface water obtained from the Galian C area, Banawa District, Donggala Regency. The study applied a quantitative laboratory experiment with four dosages, specifically 1, 3, 5, and 7 g in 50 mL of water sample. Initial and final pH, turbidity, and total suspended solids values were compared after mixing followed by 30 minutes of settling. The most favorable result occurred at 1 g/50 mL, reducing turbidity by 58.23% and TSS by 73.13%, with the final pH remaining close to neutral at 6.68.

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INTRODUCTION

Surface water located within excavation zones is frequently affected by suspended mineral matter, eroded soil particles, and fine organic residues. These substances may be transported by surface runoff into adjacent water bodies, thereby increasing turbidity and total suspended solids. This condition requires examination because turbid water not only reflects poor visual quality but may also indicate unstable suspended materials that must be treated prior to further utilization.

Excavation areas can alter the natural balance of the surrounding environment by exposing soil layers that are normally protected by vegetation or surface cover. Once these layers are disturbed, rainfall and surface runoff can more easily detach and transport particles. The resulting suspended matter may remain in surface water long enough to influence water appearance, sediment load, and basic treatment requirements. Therefore, evaluating water quality around such areas is not merely a visual assessment, but also a way to understand how physical disturbance is reflected in measurable parameters.

Over the last several years, natural coagulants have received growing attention as feasible alternatives for small-scale water treatment. Moringa oleifera is among the most widely investigated plant materials because its seeds contain positively charged biopolymers, particularly proteinaceous compounds, capable of interacting with negatively charged colloidal particles. This interaction enables fine particles to aggregate into larger flocs that can settle more readily. Recent research has shown that Moringa seed-based coagulants are able to decrease turbidity in wastewater, surface water, and low-cost clarification systems when operating conditions are appropriately controlled (Desta & Bote, 2021; Rasheed et al., 2023; Silva & Oliveira, 2024).

The success of treatment using Moringa is not governed solely by dosage. Final treatment outcomes are also affected by water characteristics, initial turbidity, pH, mixing conditions, settling duration, and the physical form of the coagulant. Insufficient dosage may leave many particles inadequately destabilized, whereas an excessive amount of seed powder may introduce residual organic matter or suspended particles into the treated sample. Accordingly, this study is directed toward determining a practical dose for local surface water from the Galian C area of Banawa District, Donggala Regency, rather than assuming that greater coagulant addition will necessarily improve treatment performance.

This study aimed to assess the effectiveness of Moringa oleifera seed powder in lowering turbidity and total suspended solids while sustaining an acceptable pH condition in surface water from the Galian C area. The research provides local experimental evidence regarding the application of a plant-derived coagulant for water affected by excavation activities.

The local context of Banawa District makes this topic relevant because excavation-related surface water is closely connected with land disturbance and sediment mobilization. Water moving across exposed soil surfaces can carry fine particles into small streams, puddles, or drainage channels near the activity area. Although the present study does not evaluate all possible chemical contaminants, the selected parameters provide an important initial indication of physical water quality. pH, turbidity, and TSS can be measured directly and can show whether a simple treatment approach is capable of improving the observable condition of the water sample.

From an applied perspective, the search for natural coagulants is associated with the need for treatment materials that are locally available, relatively simple to prepare, and potentially safer for small-scale use. Conventional coagulants are effective in many treatment systems, but they may require controlled dosing, purchase costs, and technical management. Plant-derived materials such as Moringa oleifera are therefore important to examine, especially in preliminary treatment settings where accessibility and operational simplicity are major considerations. However, scientific evaluation remains necessary so that the use of natural materials is not based solely on assumption or traditional familiarity.

The present research is positioned as an experimental evaluation rather than a broad field survey. Its main contribution lies in documenting how a local surface-water sample responds to specific masses of Moringa oleifera seed powder under a fixed sample volume and settling period. By comparing several dose levels, the study can identify whether the treatment response improves, remains stable, or declines when the amount of seed powder is increased. This focus is essential because natural coagulants may behave differently depending on the particle characteristics and the amount of organic material introduced during treatment.

Turbidity and TSS are useful indicators because both describe the presence of dispersed particles from different analytical perspectives. Turbidity provides an optical description of water clarity, whereas TSS expresses the measured mass of solids retained from the sample. Observing both parameters is therefore important because a treatment process may improve visual clarity while still leaving measurable suspended solids, or it may reduce solid mass without fully restoring water transparency.

The Galian C area is associated with extraction activities that can disturb soil structure and expose loose material to rainfall and surface flow. When these particles enter nearby water bodies, the water may retain fine solids for a relatively long period because the particles are small, light, and difficult to settle under natural conditions. This situation explains why physical water-quality indicators are relevant for evaluating surface water around excavation sites.

THEORETICAL REVIEW

Moringa oleifera as a Natural Coagulant

Coagulation is a treatment process intended to reduce particle stability so that colloids and suspended solids can combine into larger aggregates. In Moringa oleifera seeds, cationic active constituents assist this destabilization by reducing electrostatic repulsion between fine particles. Recent literature identifies Moringa seeds as renewable and biodegradable materials with the potential to lessen reliance on synthetic coagulants in selected treatment applications (Al-Jadabi et al., 2023; Nzeyimana & Mary, 2024).

A number of recent studies further indicate that the performance of Moringa oleifera differs across water matrices. In domestic wastewater treatment, Moringa seed extract has been reported to remove turbidity effectively while producing a smaller pH shift than several inorganic coagulants. For low-turbidity water, combined treatment using chemical coagulants may achieve better results than Moringa alone, indicating that application conditions must be chosen carefully (Balbinoti et al., 2024; Vega Andrade et al., 2021).

Turbidity, TSS, and pH

Turbidity denotes the optical cloudiness of water, while TSS refers to the mass concentration of suspended solids. Although related, these two parameters are not the same: turbidity indicates light scattering caused by particles, whereas TSS measures retained suspended material. pH is likewise important because it can affect particle surface charge, the behavior of natural coagulant proteins, and the suitability of treated water for subsequent use. Thus, observing pH, turbidity, and TSS together provides a more comprehensive evaluation of treatment effectiveness.

Hypothesis and Conceptual Framework

This study was formulated on the basis of two hypotheses. First, Moringa oleifera seed powder is capable of reducing turbidity and TSS in surface water from the Galian C area. Second, a higher dose does not always lead to improved treatment performance because overdosing may introduce residual particles or cause restabilization of suspended matter. The conceptual relationship examined in this study is that coagulant dose affects the coagulation-settling process, which subsequently alters pH, turbidity, and TSS values.

METHODOLOGY

This research employed a laboratory experimental method using a quantitative descriptive approach. Surface water samples were obtained from the Galian C area in Banawa District, Donggala Regency. Prior to treatment, the samples were tested to identify their initial pH, turbidity, and TSS values. These baseline measurements served as the comparison standard for all dosage treatments.

Moringa oleifera seeds were separated from their seed coats, dried, and milled into powder. Four seed-powder masses were prepared, namely 1 g, 3 g, 5 g, and 7 g. Each mass was introduced into 50 mL of surface water, resulting in equivalent concentrations of 20, 60, 100, and 140 g/L. After coagulant addition, the samples were mixed and subsequently left to settle for 30 minutes before pH, turbidity, and TSS measurements were conducted.

Table 1. Experimental Treatment Design for Moringa oleifera Seed Powder.

Treatment	Dose per 50 mL	Equivalent concentration
Control	0 g	0 g/L
P1	1 g	20 g/L

P2	3 g	60 g/L
P3	5 g	100 g/L
P4	7 g	140 g/L

Treatment effectiveness was determined by comparing each final measurement with the initial value. The percentage reduction in turbidity and TSS was calculated using the following equation: Reduction (%) = ((initial value - final value) / initial value) x 100.

RESULTS

The untreated surface water showed a pH of 8.22, turbidity of 9.48 NTU, and TSS of 640 mg/L. Following treatment, the greatest improvement occurred in the 1 g/50 mL treatment. The complete measurement results are presented in Table 2.

The baseline condition shows that the sample had slightly alkaline pH, measurable turbidity, and a relatively high TSS value. This combination suggests that the water contained suspended material that could affect clarity and physical quality. Because the initial pH was 8.22, the treatment response was also evaluated in terms of whether the added seed powder moved the pH closer to neutral or shifted it excessively toward acidity. These baseline values are central because every treatment outcome was assessed relative to them.

Table 2. Measurement Values of pH, Turbidity, and TSS

Treatment	Concentration	pH	Turbidity (NTU)	TSS (mg/L)
Untreated water	0 g/L	8.22	9.48	640
Moringa 1 g/50 mL	20 g/L	6.68	3.96	172
Moringa 3 g/50 mL	60 g/L	5.62	4.38	414
Moringa 5 g/50 mL	100 g/L	5.41	8.59	714
Moringa 7 g/50 mL	140 g/L	5.40	10.72	1676

At the lowest tested dose, turbidity declined from 9.48 NTU to 3.96 NTU, while TSS decreased from 640 mg/L to 172 mg/L. These changes corresponded to reductions of 58.23% for turbidity and 73.13% for TSS. Increasing the dose did not yield a better response; rather, the reduction became less pronounced, and at the highest dose, both turbidity and TSS were higher than their initial values.

Table 3. Turbidity and TSS Reduction Following Treatment

Treatment	Turbidity reduction	TSS reduction	Interpretation
Moringa 1 g/50 mL	58.23%	73.13%	Optimum dose in this experiment
Moringa 3 g/50 mL	53.80%	35.31%	Effective, but less consistent
Moringa 5 g/50 mL	9.39%	-11.56%	Increase in TSS
Moringa 7 g/50 mL	-13.08%	-161.88%	Increase in turbidity and TSS

The pH values also demonstrated a downward trend. The initial pH of 8.22 shifted to 6.68 at 1 g/50 mL, 5.62 at 3 g/50 mL, 5.41 at 5 g/50 mL, and 5.40 at 7 g/50 mL. Of all treatments, the 1 g dose produced the pH value closest to neutral conditions.

DISCUSSION

The results demonstrate that Moringa oleifera seed powder can enhance the physical quality of the tested surface water when applied at an appropriate dose. The 1 g/50 mL treatment was the most effective because it produced the greatest decreases in turbidity and TSS while maintaining the pH near neutrality. This finding is consistent with recent studies indicating that Moringa-based coagulants facilitate particle aggregation and sedimentation in water treatment systems (Desta & Bote, 2021; Rasheed et al., 2023; Silva & Oliveira, 2024).

The success of the 1 g/50 mL treatment indicates that Moringa oleifera seed powder can function as a natural coagulant under the experimental conditions used in this study. The decrease in turbidity suggests that fewer particles remained suspended in a way that scattered light, while the decrease in TSS shows that the mass of suspended solids also declined. The simultaneous improvement of both parameters strengthens the interpretation that the coagulant promoted particle aggregation and settling at this dose. The final pH of 6.68 at the optimum dose is also important because it shows that the treatment did not create an excessive acidic condition. A treatment that removes particles but causes strong pH deviation may require additional correction before practical use. In this experiment, the 1 g/50 mL dose provided the most acceptable balance among the three measured parameters. This balance is more meaningful than a single-parameter improvement because water quality is multidimensional.

The effectiveness of the 1 g/50 mL treatment can be interpreted as the point at which the available active components were sufficient to destabilize a major portion of suspended particles without adding excessive residual material to the sample. Under this condition, floc formation and settling likely occurred more efficiently than in the untreated sample. The simultaneous decrease in turbidity and TSS supports the interpretation that both optical clarity and suspended-solid mass improved at this dose.

The decrease in performance at higher doses represents an important finding of this study. The 3 g treatment continued to reduce turbidity and TSS, but its improvement was smaller than that produced by 1 g. At 5 g and 7 g, the larger addition of seed powder appeared to increase suspended residues in the water. This result supports the view that natural coagulants require dose optimization. Greater coagulant quantity does not automatically correspond to better water quality, particularly when the coagulant is applied as untreated powder rather than as a purified extract.

The lower performance at 3 g/50 mL suggests that additional seed powder did not improve the contact between active compounds and particles in a proportional manner. Instead, some of the added material may have remained dispersed after the settling period. Although the dose still produced reductions in turbidity and TSS compared with the initial water, the improvement was weaker than the 1 g/50 mL treatment. This result marks the beginning of a declining treatment response as the dose increased.

The results at 5 g/50 mL and 7 g/50 mL provide stronger evidence of overdosing. At these levels, the added powder may have contributed additional suspended material, increased residual organic content, or interfered with stable floc formation. Because the coagulant was used as crude powder, it contained both active and inactive fractions. The inactive fraction may become more influential when the mass added to a small water volume is too large.

This finding is consistent with the principle that coagulant application requires an optimum range. Both insufficient and excessive doses can reduce treatment effectiveness. An insufficient dose may leave particles stable, while an excessive dose may increase residual solids or shift particle interactions in an unfavorable direction. Therefore, the best dose must be identified experimentally rather than estimated only from the assumption that more coagulant will produce more removal.

The increase in TSS at higher doses may be explained by the physical contribution of the seed powder itself. Because the coagulant was applied as powder rather than as a purified extract, some fraction of the added material may have remained suspended after settling. This condition is especially plausible at the highest dose, where the quantity of added solid material was much greater than at the optimum treatment.

The pH findings further support this interpretation. Larger amounts of seed powder caused a stronger decrease in pH, suggesting that overdosing may influence not only particle removal but also the chemical condition of the treated sample. Earlier studies emphasize that pH, initial turbidity, and coagulant preparation method are key variables in Moringa-assisted coagulation (Balbinoti et al., 2024; Farghaly et al., 2021; Nzeyimana & Mary, 2024).

The pH decrease observed at higher doses may reflect the influence of seed material on the chemical environment of the sample. Although the study did not measure dissolved organic matter or buffering capacity, the pattern indicates that increasing the amount of seed powder affected more than particle removal. This is important because a practical coagulant should ideally improve physical quality while maintaining acceptable chemical conditions.

The pH values of 5.62, 5.41, and 5.40 at the higher doses suggest that excessive seed powder can push the treated water toward acidity. Such a shift could limit direct application if the treated water is intended for uses requiring near-neutral pH. Therefore, the pH result supports the conclusion that the optimum dose should be selected by considering the combined effects of treatment, not by focusing only on turbidity removal.

Maintaining pH close to neutral is important because water treatment should not only reduce visible contamination but also preserve chemical suitability. The 1 g/50 mL dose produced the most balanced outcome because it reduced turbidity and TSS while keeping the final pH at 6.68. This value indicates that the treatment improved the measured physical parameters without creating a strong acidic shift.

In comparison with recent literature, the removal percentages obtained in this study were moderate rather than exceptionally high. This outcome is reasonable because the experiment used simple seed powder, a brief settling period, a small sample volume, and no additional filtration stage. Studies that employ extracted active compounds, optimized pH, or combined clarification units commonly report higher turbidity removal. Therefore, the present findings should be regarded as preliminary local evidence and as a basis for further optimization, rather than as a final treatment design.

The moderate removal percentage may also be linked to the absence of additional treatment steps. In many water treatment systems, coagulation is followed by filtration to capture smaller residual particles that do not settle completely. The present experiment used only mixing and settling before measurement. Therefore, some particles or seed residues may have remained in the treated sample, limiting the final reduction values.

Another possible reason for the moderate performance is the relatively short contact and settling duration. A 30-minute period can show an early treatment response, but some flocs may require longer time to form or settle fully. Future experiments with several settling durations could determine whether the same dose produces higher removal after longer sedimentation. Such testing would be useful for distinguishing between true dose limitation and insufficient settling time.

The use of crude seed powder also differentiates this study from investigations using extracts or processed active compounds. Extracted coagulants may contain a higher proportion of active material and fewer residual particles, which can lead to stronger clarification. However, extraction requires additional preparation and may reduce the simplicity that makes Moringa attractive for local application. The present results therefore reflect the performance of a practical, low-processing approach rather than an optimized laboratory extract.

From a local environmental perspective, the findings suggest that Moringa oleifera seed powder could serve as an initial clarification option for surface water influenced by excavation activity. Nevertheless, the method should not be presented as a complete treatment system based only on the present results. The study evaluates three basic parameters, while broader water quality also includes microbiological, chemical, and organic indicators. Thus, the method is better understood as a preliminary physical treatment that may need to be integrated with further purification steps.

Overall, the study indicates that Moringa oleifera seed powder has potential as a locally applicable natural coagulant, but its use should be based on dose optimization. The strongest practical implication is that the lowest tested dose performed best under the conditions of this experiment. This finding is useful for future testing because it provides a starting point for refining dose ranges, settling time, and post-treatment filtration.

CONCLUSIONS AND RECOMMENDATIONS

Moringa oleifera seed powder effectively improves surface water quality at a dose of 1 g/50 mL, or the equivalent of 20 g/L. At this dose, turbidity decreased by 58.23%, TSS decreased by 73.13%, and pH reached 6.68. This dose yielded the best results in this study because it reduced both turbidity and TSS while maintaining a pH close to neutral.

Increasing the dose above 1 g/50 mL does not always improve treatment effectiveness. At higher doses, particularly 7 g/50 mL, turbidity and TSS values actually exceeded initial conditions. This indicates that the use of natural coagulants still requires precise dose control, as excessive addition of the material can worsen water quality.

In general, Moringa oleifera seed powder has the potential to be used as a natural coagulant for surface water, particularly in water sources affected by Galian C activities. However, the 1 g/50 mL dose should be understood as the optimal dose under the conditions of this experiment, not as a universal dose for all types of water or seasons.

For practical application, dose optimization is necessary before use in larger volumes of water. Repeated testing with a larger number of samples is also required to ensure more reliable results. The treatment process should be conducted under controlled conditions, including accurate dose measurement, thorough mixing, sufficient settling time, careful separation of clear water from the sediment, and filtration to reduce residual seed particles.

Further research is recommended using a narrower dosage range around 1 g/50 mL to determine a more precise optimum point. Additionally, the seed source, maturity level, drying process, and method of powder preparation need to be described in detail as they can affect the active content and effectiveness of the coagulant. Thus, the use of Moringa oleifera as a natural coagulant can be applied in a more scientific, safe, and appropriate manner for local water characteristics.

FURTHER STUDY

This study was restricted to one water source, four dosage levels, and a single settling duration. Future studies should include experimental replication, jar-test optimization, varied settling times, control of seed-powder particle size, comparison with aluminum sulfate or PAC, and measurement of organic matter and microbial indicators.

Further study should also examine the effect of particle size in the seed powder. Finer powder may increase contact with suspended particles, but it may also be more difficult to remove after settling. Coarser powder may settle more easily but may expose fewer active sites. Comparing different powder sizes would help determine whether the treatment can be improved without using chemical extraction.

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