

Investigation of turbidity removal using combined cactus and moringa seed powders

Bezu Abera Geresu^{ID}, Chali Dereje Kitila^{ID}, Dejene Beyene^{ID}

Department of Water Supply and Environmental Engineering, Faculty of Civil and Environmental Engineering, Jimma Institute of Technology, Jimma University, Jimma, Ethiopia

Abstract

Background: Turbidity in surface water has been effectively reduced through the use of synthetic coagulants. However, despite their advantages, these synthetic options can result in significant environmental pollution and often come with high costs that may be prohibitive for many users. The present study investigated the coagulant potential of the grounded seeds of cactus and moringa as cost-effective, innovative, and eco-friendly alternatives in the water treatment industry.

Methods: Experimental research was used to investigate the efficiency of a combined moringa and cactus powder in removing turbidity from the water samples. The moringa to cactus percentage ratios: 50:50, 75:25, and 25:75; settling time: 30, 40, and 50 minutes; stirring speeds: 30, 40, and 60 rpm; and pH levels: 5, 7, and 9 were used to examine the turbidity removal efficiency of the blended coagulants. The Central Composite Design (CCD) from Response Surface Methodology (RSM) was used to optimize the treatment conditions.

Results: A coagulant ratio (g) of 3:1 (75% moringa: 25% Cactus), settling time of 40 min, stirring speed of 50 rpm, and pH 7 are the optimum conditions to achieve the highest removal efficiency.

Conclusion: The study clearly indicated that combining powdered Cactus and moringa seeds improves turbidity reduction efficiency. The blend coagulant is a promising, eco-friendly alternative coagulant to conventional coagulants used in water treatment.

Keywords: Cactus powder, Eco-friendly, Moringa seed, Response surface methodology, Turbidity removal

Citation: Geresu BA, Kitila CD, Beyene D. Investigation of turbidity removal using combined cactus and moringa seed powders. Environmental Health Engineering and Management Journal. 2025;12:1412. doi:10.34172/EHEM.1412.

Article History:

Received: 13 August 2024

Revised: 15 March 2025

Accepted: 16 March 2025

ePublished: 11 November 2025

*Correspondence to:

Bezu Abera Geresu,

Email: filigeresu@gmail.com

Introduction

Clean drinking water is essential for health, as contaminated water is the main cause of disease, particularly in children (1). Food and water-borne pathogens are responsible for 50% pediatric diseases and fatalities. According to the World Health Organization (WHO), about 80% global diseases and poor health conditions are attributed to inadequate sanitation, unsafe water, and limited access to clean water (2). Access to safe and clean water remains a significant challenge in many developing countries.

Water pollution, a major contributor to waterborne diseases such as diarrhea, is responsible for over six million deaths annually. The high cost of importing chemicals for water purification exacerbates this issue. To ensure water safety and consumer acceptance, various treatment techniques are employed, depending on the specific characteristics of the raw water. The substantial seasonal fluctuations of color, turbidity, total dissolved solids (TDS), nitrates, phosphates, and nitrites are

challenges in surface water treatment.

Ferric salts (e.g., FeCl_3 and $\text{Fe}_2(\text{SO}_4)_3$) as well as aluminum salts (e.g., AlCl_3) are the most commonly used inorganic coagulants in conventional water purification. While these chemicals are effective coagulants, their use presents several drawbacks, including high operational costs, maintenance requirements, and the production of large volumes of sludge, which can complicate waste management and increase treatment costs (3). Excessive use of chemical coagulants, particularly aluminum-based compounds, may pose potential risks to human health. A prolonged consumption of residual aluminum from water has been linked to neurological disorders, including dementia (4).

Natural coagulants derived from plant seeds, leaves, and roots have proven effective in treating surface water. Moringa seed powder, in particular, has demonstrated coagulating properties that help reduce turbidity, alkalinity, total dissolved solids (TDS), and water hardness,



making it an effective alternative for water purification (5). Moringa seeds have a long history of use in rural communities for household water purification. Moringa is widely recognized for its ability to filter pollutants and improve water quality (6).

Moringa oleifera seeds, in particular, are widely utilized in many countries to reduce turbidity due to the presence of proteins with effective coagulation properties (7). When processed and added to contaminated water, cactus extract functions as a flocculent, facilitating the aggregation of sediments and bacteria, which settle at the bottom, resulting in the removal of up to 98% of contaminants (8,9). In this study, a strategy that leverages the effective use of blended cactus extract and powdered moringa seed as a natural coagulant to address the health challenges of drinking untreated water has been addressed.

Materials and Methods

Study design

The laboratory experiment was conducted following a well-structured experimental design, carried out in distinct phases (Figure 1). The process began with sample collection and concluded with the attainment of the defined objectives.

Data Sources

In this study, both primary (cactus and moringa seeds) and secondary data were collected.

Primary data

Cactus and moringa seed samples were collected from various areas of Jimma zone, southwest Ethiopia.

Secondary Data

Manuals, periodicals, journals, book sections, dissertations, previous reports, and files maintained by accountable organizations provided the secondary data for the study, which was then interpreted and analyzed.

Equipment and materials used

Test tube, graduated cylinder, reagent bottle, Spatula, paper, pH meter, nitrate meter instrument, Pan-shallow, Sieve- a utensil consisting of a wire or plastic mesh held in a frame, Mortar, pestle, oven tray (oven), beaker, jar test apparatus, turbidity meter, and spectrophotometer are the tools employed in this investigation.

The process for preparing *Moringa oleifera* samples

The *Moringa oleifera* seeds were purchased from a local market and first sun-dried to reduce their moisture content. The husks were then removed, and the seeds were crushed using a mortar. Afterward, the seeds were oven-dried at 100°C for five hours to further reduce moisture. A mortar and pestle were used to grind the dried cactus extract and Moringa seeds into a powder, whereas a sieve

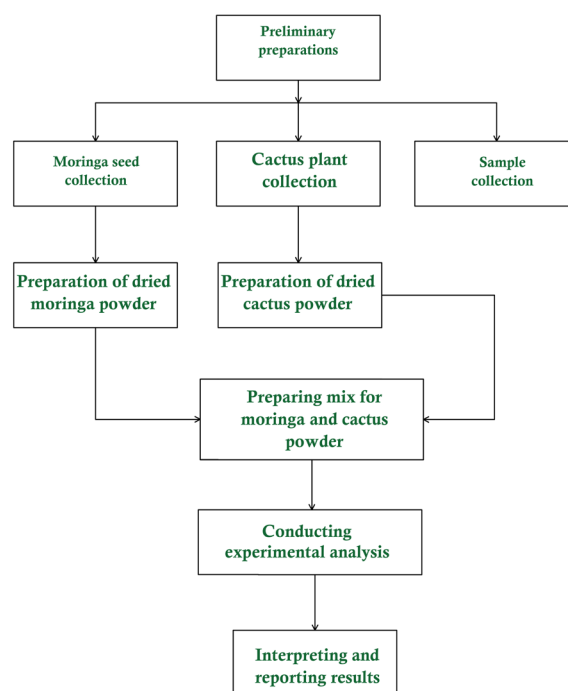


Figure 1. Research design

was used to separate fine particulates from coarse ones.

The procedure for the preparation of Cactus samples

Distilled water was used to wash the freshly collected cactus leaves to remove impurities. Cactus shoots were crushed into smaller pieces and dried in an oven at 100°C for 10 h until a weight loss of 44% was achieved. The dried cactus was ground into powder with an electric grinder and sieved through a 125 µm mesh to ensure uniformity (1) (Figure 2).

Coagulation experiments using mixed cactus and moringa

The cactus and moringa seed powders were mixed at different weight ratios and mixed with a one-liter water sample to investigate the turbidity removal efficiency of the blended coagulants (1) (Figure 3). The coagulants were mixed according to the following proportions:

1. M (50%): C (50%)
2. M (25%): C (75%)
3. M (75%): C (25%)

Where *M* is moringa and *C* is a cactus.

The coagulation experiments were conducted at different settling velocities, pH, and settling times.

Experimental setup and procedures

Adjusting pH

The acidic, neutral, and alkaline pH ranges corresponding to 5, 7, and 9 were selected for the study. Chemicals like sodium hydroxide with normalcy of 0.02N and diluted sulfuric acid were employed to reach these pH levels (9).

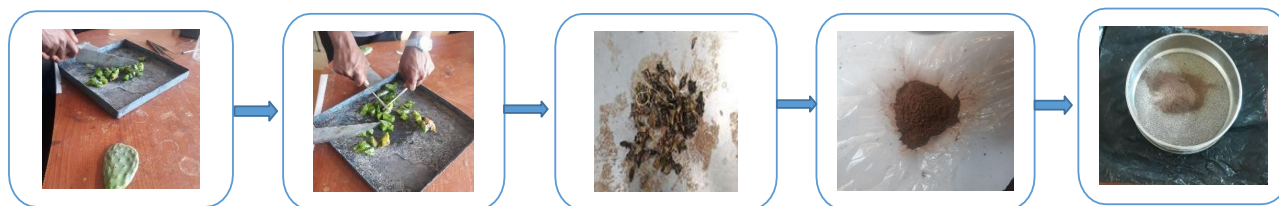


Figure 2. Preparations of cactus powder



Figure 3. Different mix ratios of Cactus and Moringa coagulants used in the experiment

The Jar Test

Jar test (Stuart Scientific Flocculator SW1) setup with six beakers and steel spindle paddles was used to coagulate the water sample containing different coagulant ratios. Before the jar test, the water samples were thoroughly mixed to ensure uniformity. The study indicated that the jar test results were significantly influenced by the coagulant dose, settling time, and stirring speed. The mixing phase began with two minutes at 60 revolutions per minute (rpm) to ensure thorough blending of the coagulants with the water. After the water was homogenized, the stirring speed, also known as the string speed, was maintained above the required mixing speed for 50 minutes. Once the mixing phase was complete, the suspended solids were allowed to settle during the specified settling time.

Turbidity

After putting a sample of water into the beaker, the turbidity meter was calibrated, added to the sample, and the measurement was recorded. The tool used to measure turbidity is the turbidity meter. The general formula used to calculate the percentage of turbidity reduction.

$$\text{Removal efficiency of turbidity} = \frac{(TUR_i - TUR_f)}{(TUR_i)} \times 100\%$$

Where TUR_i is the turbidity of the raw sample and TUR_f is turbidity after treatment.

Results

Developing a model and optimizing variables

The RSM model was used to build and optimize variables. Three levels of adjustments were made to the four independent variables to maximize turbidity removal efficiency (10). Using CCD designs, 28 experimental runs were conducted to investigate the effect of different

variables on turbidity removal efficiency (Table 1). Regression analysis was performed using the results to develop a quadratic model equation to evaluate the removal efficiency as a function of the coded variables. A center point (β_0), four quadratic terms (A^2 , B^2 , C^2 , and D^2), six interaction terms (AB , AC , AD , BC , BD , and CD), and four linear terms (A , B , C , and D) make up the equation. The magnitudes of the regression coefficients were used to infer the significance level of the variables. In this case, the settling time and coagulant dose were shown to be the most significant criteria. Thus, the RSM model has been successfully applied to ascertain the dependent factors' level of significance as well as the relationship between water purification and factors. The point of prediction methodology was used to forecast the ideal level of variables. Table 1 details the removal effectiveness of moringa cactus under various conditions.

Model fitting and statistical evaluation of the turbidity removal efficiency

The significance of the model is indicated by its F-value of 243.18. The likelihood that an F-value is great may be caused by noise is 0.01%. Model terms are considered significant when the P-value is less than 0.0500. A , B , C , D , AB , AC , BD , CD , A^2 , B^2 , and D^2 are significant model terms (11). The model terms are not significant if their values exceed 0.1000 (Table 2). Model reduction may enhance the model if it has a large number of unnecessary terms (apart from those needed to maintain hierarchy) (12,10).

The significance of both individual and interaction variables on turbidity reduction and model fitness was confirmed using the ANOVA (12). The variables examined were statistically significant at the 95% confidence level,

Table 1. RSM analyzed results of turbidity removal efficiency

Run	Factors				Turbidity removal (%)	
	A: pH	B: Settling time (min)	C: Stirring speed (rpm)	D: Dosage (Moringa to cactus ratio) g	Actual value	Predicted value
1	7	40	50	0.33	90.00	90.00
2	7	40	50	3	92.00	91.77
3	5	50	60	3	83.00	83.07
4	9	30	40	0.33	82.00	81.96
5	7	30	50	1.665	87.00	87.11
6	9	50	60	3	85.00	85.01
7	7	40	40	1.665	91.00	90.77
8	7	40	50	1.665	90.00	90.17
9	5	30	40	0.33	81.00	81.01
10	7	40	50	1.665	90.00	90.17
11	5	30	40	3	87.00	86.79
12	5	40	50	1.665	86.00	85.66
13	9	50	40	0.33	87.00	87.01
14	5	30	60	0.33	80.00	80.24
15	5	50	40	0.33	87.00	87.07
16	7	40	50	1.665	90.00	90.17
17	9	30	40	3	88.00	88.24
18	7	50	50	1.665	90.00	89.66
19	9	30	60	0.33	83.00	82.68
20	7	40	50	1.665	90.00	90.17
21	5	30	60	3	83.00	83.01
22	9	40	50	1.665	87.00	87.11
23	9	50	40	3	88.00	87.79
24	5	50	40	3	87.00	87.35
25	5	50	60	0.33	86.00	85.79
26	9	30	60	3	86.00	85.96
27	7	40	60	1.665	89.00	89.00
28	9	50	60	0.33	87.00	87.24

as indicated by the model's high sum of squares value (265.43, $P < 0.0001$, and F-value of 243.18). The statistical analysis of variables indicated that model parameters: A (pH, $P < 0.0001$), B (Settling time, $P < 0.0001$), C (Stirring speed, $P < 0.0001$), D (Dosage (Moringa to cactus ratio), $P < 0.0001$), AC (pH and Stirring speed, $P < 0.0001$), CD (Stirring speed and Dosage (Moringa to cactus ratio term), $P < 0.0001$), A2 (pH, $P < 0.0001$), B2 (Settling time quadratic term, $P < 0.0001$), C2 (Stirring speed quadratic term, $P < 0.0001$), and D2 (Dosage (Moringa to cactus ratio quadratic term), $P < 0.0001$) were significant. However, AD (pH and (Dosage (Moringa to cactus ratio)), interaction term, $P = 0.0961$), BC (Settling time and Stirring speed), and C² (Stirring speed, $P = 0.1187$) were not significant model factors. According to Table 2, the linear model parameters are more important than the quadratic and interaction model components. The model's P value of less than 0.0001 indicates that the likelihood of producing a high F-value as a result of noise is less than 0.01%. The

lack of fit insignificance ($P = 0$) indicates that the model is consistent with the experimental data. Additionally, it implies that the independent and dependent variables have a sufficiently high correlation.

Fit Summary

The coefficient of determination (R^2) was used to assess the model's fitness to the experimental data. The R^2 indicates how differently independent and dependent variables might vary (12). A higher R^2 score indicates a better fit between the model's predicted and experimental findings. With an R^2 value of 0.9962, the study shows that 99.62% of the experimental results match the data that the model predicted.

The model's good fit to the experimental data is demonstrated by the adjusted coefficient of determination (adjusted R^2). When favorable variables are added to the model, adjusted R^2 increases; however, when undesirable variables are included, it falls. The larger predicted R^2 value

Table 2. ANOVA for the Quadratic Model of turbidity

Source	Sum of Squares	df	Mean Square	F-value	P value	
Model	264.42	14	18.89	243.18	<0.0001	Significant
A-PH	9.39	1	9.39	120.89	<0.0001	
B-settling time	29.39	1	29.39	378.40	<0.0001	
C-stirring speed	14.22	1	14.22	183.12	<0.0001	
D-dosage (Moringa to cactus ratio)	14.22	1	14.22	183.12	<0.0001	
AB	1.0000	1	1.0000	12.88	0.0033	
AC	2.25	1	2.25	28.97	0.0001	
AD	0.2500	1	0.2500	3.22	0.0961	
BC	0.2500	1	0.2500	3.22	0.0961	
BD	30.25	1	30.25	389.49	<0.0001	
CD	9.00	1	9.00	115.88	<0.0001	
A ²	37.05	1	37.05	477.02	<0.0001	
B ²	8.26	1	8.26	106.40	<0.0001	
C ²	0.2167	1	0.2167	2.79	0.1187	
D ²	1.30	1	1.30	16.75	0.0013	
Residual	1.01	13	0.0777			
Lack of Fit	1.01	10	0.1010			
Pure Error	0.0000	3	0.0000			
Cor Total	265.43	27				

was used to infer the model's fitness to the experimental data. The unimportant model terms were removed, as indicated by the 0.0153 difference between predicted R^2 and adjusted R^2 (Table 3).

The best model approach for variables optimization and maximization of removal efficiency was identified using the Design Expert® program Version 13.5.0 (Stat-Ease, Inc., USA). The R^2 , adjusted R^2 , predicted R^2 , SD, and PRESS were used to determine which model best fit (12). According to the model fit statistical data (Table 3), the quadratic model fits better than the non-aliased models (i.e., linear and 2FI). It also shows the lowest standard deviation (SD) and PRESS values, as well as the greatest R^2 , adjusted R^2 , and predicted R^2 values.

A CV value of less than 10% indicates a more accurate and reliable model and a reproducible set of experimental data (13). Thus, the experimental results have a higher degree of precision and good dependability, as indicated by the present study's CV value of 0.3209%. Further evidence that the quadratic model is suitable for forecasting removal efficiency comes from its lower SD value and R^2 value, approaching unity.

A difference of less than 20% between adjusted R^2 and predicted R^2 indicates a good agreement between the experimental and model-predicted data (14). The measurement of the signal-to-noise ratio was accurate enough. In general, it is better to have an Adequate Precision > 4.0. The appropriate precision for this study was determined to be 56.5563, indicating that the quadratic model is accurate and that there is adequate signal to handle the impacts of variables on removal efficiency. The

quadratic model's predicted R^2 value of 0.9768 validates its capacity to forecast the decrease in turbidity. In conclusion, based on all statistical features, the quadratic regression model equation is highly reliable and accurate for calculating removal effectiveness (Table S1).

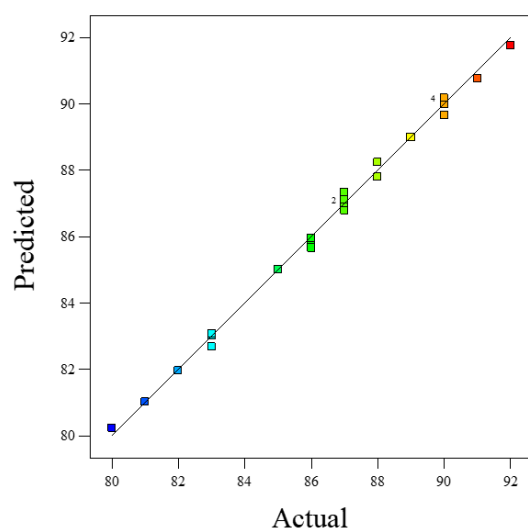
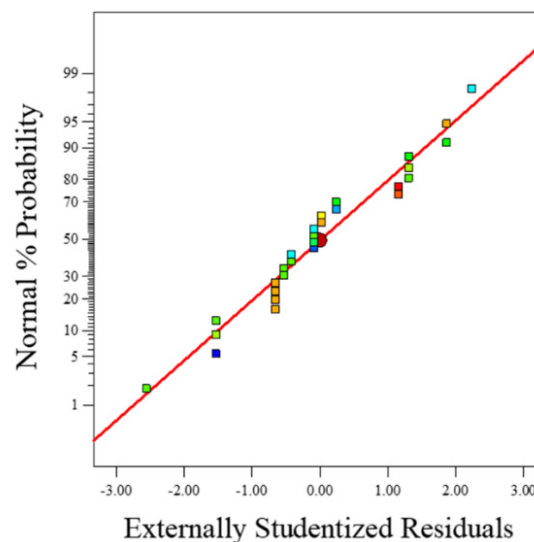
Plotting the estimated turbidity reduction yield against the actual yield shows that the expected results closely match the experimental results. A good fit between the experimental and expected data is indicated by a data point that deviates little from the diagonal line (15). The differences between the experimental and projected values < 0.20 (Figure 4) indicate a high-quality agreement between the model-anticipated and experimental turbidity removal efficiency. The outcome is consistent with the R^2 and adjusted R^2 values, which are quite close to 1. It may be concluded that the regression model offers a trustworthy estimate of the turbidity removal yield in light of variations in the independent variables under investigation.

The residuals have a normal distribution as long as the experimental errors are random. The normal distribution of the residuals indicates the validity of the quadratic regression model (16). Studentized residuals were created by normalizing the residuals and dividing them by their estimated standard deviations (16). Plotting the studentized residuals against the studentized residuals obtained from the experimental data allowed for the prediction of the best-fit normal distribution. The studentized residuals have a normal distribution, as seen by the data points along the straight line (Figure 5).

The residuals' normal distribution plot indicates that

Table 3. Model Summary Statistics for turbidity removal

Source	Std. Dev.	R ²	Adjusted R ²	Predicted R ²	PRESS	
Linear	2.94	0.2533	0.1234	-0.1091	294.39	
2FI	3.02	0.4153	0.0713	-0.9916	528.64	
Quadratic	0.2787	0.9962	0.9921	0.9768	6.15	Suggested
Cubic	0.2154	0.9991	0.9953	0.8757	32.99	Aliased

**Figure 4.** Plot of actual vs predicted turbidity removal**Figure 5.** Normal % probability vs externally

the quadratic regression model is adequate, reliable, and offers a better estimate of the turbidity removal efficiency when the factors under investigation vary (Figure 6).

Discussion

Effects of variables on the turbidity removal

Three-dimensional (3D) response surface curves were used to examine how different variables interacted to remove turbidity. By maintaining two variables at their center points, these interactions were investigated (17). Up to an optimal point (18), a positive coefficient for the interaction variables means that the removal efficiency increases as both variables increase. Efficiency declines as the variables increase past this optimal point (19).

Figure 6A shows the response surface curve for the interaction effects of pH and dosage (moringa and cactus) on the efficacy of turbidity reduction. The turbidity removal efficiency falls to less than 88% when the pH is less than 6 and higher than 9, but it reaches over 90% when the dosage is more than 1.932 g and the pH range is between 6 and 8. The removal of turbidity from surface water can be achieved by combining moringa with cactus in different ranges and interacting with diverse pH ranges (6 to 8). However, this method is ineffective for treating the water's acidity or basic qualities.

The response surface curve for the interaction effects of settling time (ST) and dosage M & C (Moringa and Cactus) on the effectiveness of turbidity reduction is displayed in Figure 6B. When the dosage is greater than 1.932 g and

the settling time is 45 to 50 minutes, the removal efficacy is greater than 90%. When the ST is between 45 and 50, the turbidity reduction efficiency drops to less than 88%.

The interaction effect of pH and settling time on turbidity removal efficiency is shown in Figure 6c, with settling time and pH falling between 30 and 50 minutes, and 5 to 9, respectively. When the pH is between 6 and 8 and the settling time is over 50 minutes, the removal efficiency is above 90%. However, the removal efficiency falls below 84% when the pH is below 6 or above 9 and the settling time is less than 40 minutes (19).

In conclusion, using a variety of cacti and moringa and interacting with them for varying lengths of time (45 to 50 minutes) can successfully remove turbidity from surface water.

Experimental validation of optimum removal yield

The point prediction tool in the Design Expert® 13 application was used to solve the quadratic equation and determine the ideal value for the turbidity removal variables that would result in the highest removal efficiency after limiting the maximum and minimum of the variables. While the other criteria were set to “in range,” the turbidity removal efficiency criterion was set to “maximize.” The following four confirmatory experiments were conducted in duplicate under optimal removal conditions: pH (5, 7, and 9) combined at room temperature; settling and stirring times (30, 40, and 60 minutes); dosage (Moringa cactus; 50%M: 50%C, 25%M:

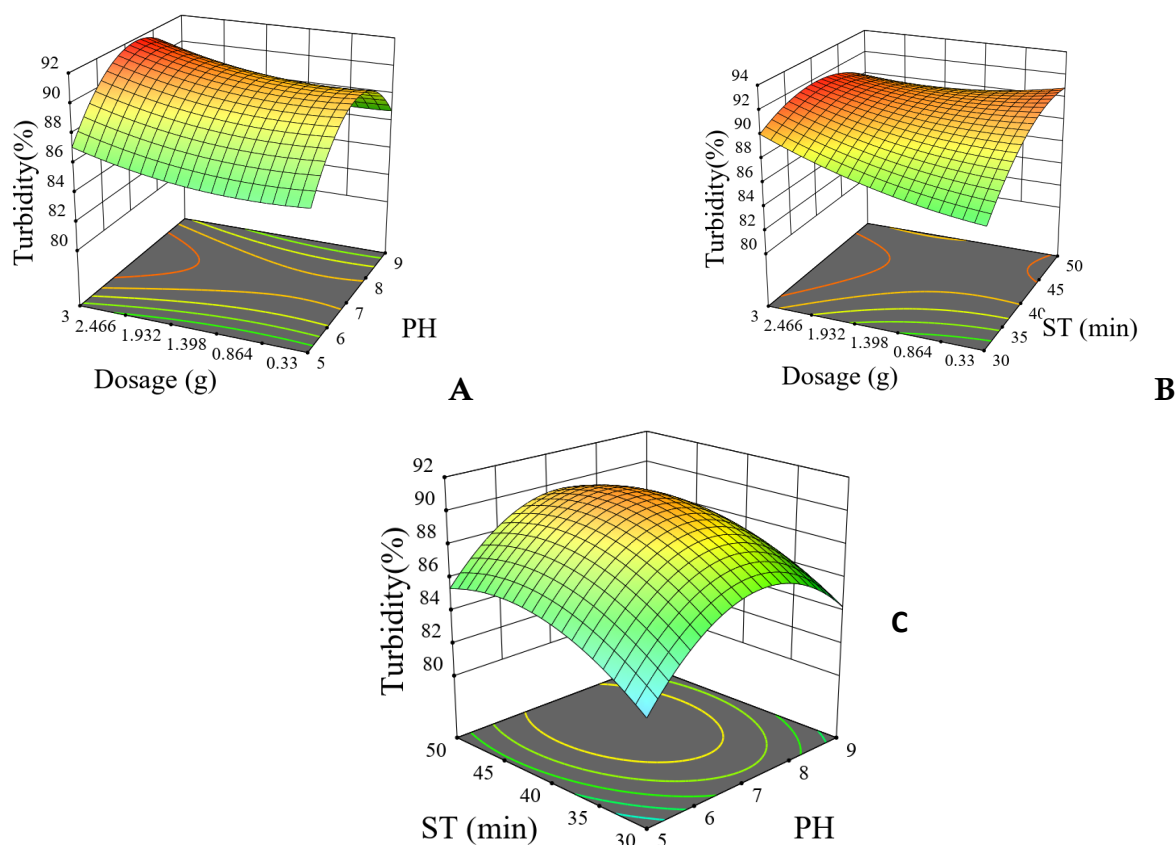


Figure 6. Interaction of dosage, pH, and settling time on turbidity removal efficiency

75%C, and 75%M: 25%C). This was carried out to validate the model's anticipated optimal removal efficiency (12).

From the validation studies, an actual turbidity removal effectiveness of 97.68.00% was found. This removal efficiency aligns well with the model-projected result of 99.21% (Mean $\pm$ SD; $n=4$). The minimal discrepancy between the observed and anticipated values demonstrates the accuracy of the proposed quadratic model and confirms the optimal conditions for achieving the highest possible efficiency in turbidity reduction. The efficiency of natural coagulants, such as Moringa and its combinations with other coagulants, in removing turbidity from surface water has been studied. When compared to our results, the efficiency observed in these studies is relatively similar to what we achieved (Table 4).

Conclusion

The study emphasizes how well cactus plants and moringa seeds work as natural coagulants in water treatment, providing an affordable and environmentally friendly substitute for artificial chemicals. These materials were used in the coagulation-flocculation process, which effectively decreased turbidity and eliminated contaminants from surface water. Cactus produced larger, more stable flocs, whereas Moringa showed greater turbidity reduction. The study found that the highest

Table 4. The compression of natural coagulants

Turbidity removal (%)	References
89 to 96	(20)
90.46, and 88.57	(21)
24.2 and 22.2	(22)
80 and 70	(23)

removal efficiency was achieved with a 75% Moringa and 25% Cactus mix at a pH of 7, settling time of 45 to 50 minutes, and stirring speed below 50 rpm. This was accomplished by experimenting with different mixing ratios of Moringa and Cactus (50%M:50%C, 75%M:25%C, and 25%M:75%C), as well as varying parameters like pH, stirring speed, and settling time. The effectiveness and dependability of this natural coagulant mixture were confirmed by the fact that the actual turbidity clearance of 92% nearly matched the expected value of 91.77%. According to these results, purifying surface water in low-income areas using locally obtained moringa and cacti could be a practical and affordable method of lowering the prevalence of waterborne diseases.

Acknowledgments

The authors would like to express their gratitude to Jimma University and Jimma Institute of Technology for their unwavering support of this experimental investigation.

Author's contributions

Conceptualization: Dejene Beyene.

Data curation: Bezu Abera Geresu.

Formal analysis: Chali Dereje Kitila.

Funding acquisition: Bezu Abera Geresu.

Investigation: Bezu Abera Geresu.

Methodology: Dejene Beyene.

Project administration: Bezu Abera Geresu.

Resources: Dejene Beyene.

Software: Bezu Abera Geresu.

Supervision: Dejene Beyene.

Validation: Chali Dereje Kitila.

Visualization: Chali Dereje Kitila.

Writing—original draft: Bezu Abera Geresu.

Writing review & editing: Chali Dereje Kitila.

Competing interests

The authors declared no conflicts of interest.

Ethical issues

The data collected for the study were completely identified in the publication, and the authors confirm that no data from the study have been or will be published separately elsewhere.

Funding

This study was financially supported by Jimma Institute of Technology, Jimma University.

Supplementary files

Supplementary file 1 contains Tables S1

References

- Sedlak D. Water 4.0: The Past, Present, and Future of the World? S Most Vital Resource. Yale University Press; 2014.
- World Health Organization (WHO). Safer Water, Better Health. WHO; 2019.
- Kumar V, Othman N, Asharuddin S. Applications of natural coagulants to treat wastewater—a review. MATEC Web Conf. 2017;103:06016. doi: [10.1051/mateconf/201710306016](https://doi.org/10.1051/mateconf/201710306016).
- Walton JR. Chronic aluminum intake causes Alzheimer's disease: applying Sir Austin Bradford Hill's causality criteria. J Alzheimers Dis. 2014;40(4):765-838. doi: [10.3233/jad-132204](https://doi.org/10.3233/jad-132204).
- Shan TC, Matar MA, Makky EA, Ali EN. The use of *Moringa oleifera* seed as a natural coagulant for wastewater treatment and heavy metals removal. Appl Water Sci. 2017;7(3):1369-76. doi: [10.1007/s13201-016-0499-8](https://doi.org/10.1007/s13201-016-0499-8).
- Bichi MH. A review of the applications of *Moringa oleifera* seeds extract in water treatment. Civ Environ Res. 2013;3(8):1-10.
- Ndabigengesere A, Narasiah KS, Talbot BG. Active agents and mechanism of coagulation of turbid waters using *Moringa oleifera*. Water Res. 1995;29(2):703-10. doi: [10.1016/0043-1354\(94\)00161-y](https://doi.org/10.1016/0043-1354(94)00161-y).
- Yetman D. The Great Cacti: Ethnobotany & Biogeography. University of Arizona Press; 2007.
- Gebreyohannes N. Contamination Assessment and Optimization of Coagulation-Flocculation-Sedimentation Water Treatment Process for Kou River in Northern Tanzania [dissertation]. Arusha: NM-AIST Repository; 2022. doi: [10.58694/20.500.12479/1645](https://doi.org/10.58694/20.500.12479/1645).
- Tong ST, Chen W. Modeling the relationship between land use and surface water quality. J Environ Manage. 2002;66(4):377-93. doi: [10.1006/jema.2002.0593](https://doi.org/10.1006/jema.2002.0593).
- Yildiz Z, Sarimeseli A. Optimization of osmotic dehydration of organic red pepper using response surface methodology. Int J Eng Appl Sci. 2015;7(4):19-33. doi: [10.24107/ijeas.251258](https://doi.org/10.24107/ijeas.251258).
- Beyene D, Bekele D, Abera B. Biodiesel from blended microalgae and waste cooking oils: optimization, characterization, and fuel quality studies. AIMS Energy. 2024;12(2):408-38. doi: [10.3934/energy.2024019](https://doi.org/10.3934/energy.2024019).
- Zuo XN, Anderson JS, Bellec P, Birn RM, Biswal BB, Blautzik J, et al. An open science resource for establishing reliability and reproducibility in functional connectomics. Sci Data. 2014;1:140049. doi: [10.1038/sdata.2014.49](https://doi.org/10.1038/sdata.2014.49).
- Chicco D, Warrens MJ, Jurman G. The coefficient of determination R-squared is more informative than SMAPE, MAE, MAPE, MSE and RMSE in regression analysis evaluation. PeerJ Comput Sci. 2021;7:e623. doi: [10.7717/peerj-cs.623](https://doi.org/10.7717/peerj-cs.623).
- McCabe JC. Observations of Estuarine Turbulence and Floc Size Variations [dissertation]. University of Plymouth; 1991. doi: [10.24382/4797](https://doi.org/10.24382/4797).
- Martin J, de Adana DD, Asuero AG. Fitting models to data: residual analysis, a primer. In: Hessling JP, ed. Uncertainty Quantification and Model Calibration. London: IntechOpen; 2017. doi: [10.5772/68049](https://doi.org/10.5772/68049).
- Rezania N, Hasani Zonoozi M, Saadatpour M. Coagulation-flocculation of turbid water using graphene oxide: simulation through response surface methodology and process characterization. Environ Sci Pollut Res Int. 2021;28(12):14812-27. doi: [10.1007/s11356-020-11625-y](https://doi.org/10.1007/s11356-020-11625-y).
- Bhatti MS, Reddy AS, Thukral AK. Electrocoagulation removal of Cr(VI) from simulated wastewater using response surface methodology. J Hazard Mater. 2009;172(2-3):839-46. doi: [10.1016/j.jhazmat.2009.07.072](https://doi.org/10.1016/j.jhazmat.2009.07.072).
- Geresu BA, Ebba M. Investigations on the removal of phosphate and nitrate using a mixture of cactus and *Moringa* seed powder via RSM techniques. Desalin Water Treat. 2024;320:100856. doi: [10.1016/j.dwt.2024.100856](https://doi.org/10.1016/j.dwt.2024.100856).
- Asrafuzzaman M, Fakhruddin AN, Hossain MA. Reduction of turbidity of water using locally available natural coagulants. ISRN Microbiol. 2011;2011:632189. doi: [10.5402/2011/632189](https://doi.org/10.5402/2011/632189).
- Jadhav MV, Mahajan YS. Assessment of feasibility of natural coagulants in turbidity removal and modeling of coagulation process. Desalin Water Treat. 2014;52(31-33):5812-21. doi: [10.1080/19443994.2013.816875](https://doi.org/10.1080/19443994.2013.816875).
- Ahmad A, Sheikh Abdullah SR, Abu Hasan H, Othman AR, Ismail N. Potential of local plant leaves as natural coagulant for turbidity removal. Environ Sci Pollut Res Int. 2022;29(2):2579-87. doi: [10.1007/s11356-021-15541-7](https://doi.org/10.1007/s11356-021-15541-7).
- Šćiban M, Klasnja M, Antov M, Skrbić B. Removal of water turbidity by natural coagulants obtained from chestnut and acorn. Bioresour Technol. 2009;100(24):6639-43. doi: [10.1016/j.biortech.2009.06.047](https://doi.org/10.1016/j.biortech.2009.06.047).