Proceedings of 14th IOE Graduate Conference
Peer Reviewed
Year: 2023 Month: December Volume: 14
ISSN: 2350-8914 (Online), 2350-8906 (Print)

Potential Application of Banana Shoot System as Coagulant for Turbidity Removal

Rupesh K.C. [a], Poonam Baidya [b]

[a] *Department of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[b] *Department of Applied Sciences and Chemical Engineering Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[a] rupeshkathayat.123@gmail.com, [b] poonambaidya@gmail.com

Abstract
Coagulation-flocculation involves the clumping of particles into larger flocs employing a water treatment process. The utilization of synthetic coagulants presents issues of health and affordability, particularly in developing nations. Evidence shows natural coagulants have been used historically even in developed countries. Thus this study aims to introduce and validate the efficiency of one of such natural coagulants i.e. banana (shoot system) as an accessible, cost-effective, and ecologically friendly local coagulant. The research evaluated the different banana shoot systems' performance in achieving optimal turbidity removal. The study basically includes banana leaves, pith (stem), and banana fruit peels, all considered to be waste materials from banana plantations. Two different soils (pottery clay soil and talaiya soil) samples of synthetic turbid water were prepared for the study with turbidity ranging from 0 to 200 NTU. Among the banana shoot system, the pith showed the maximum ability to reduce the turbidity (85%) in water followed by peels. The efficiency of the coagulant property of banana pith in clay soil was similar to that of talaiya soil (90%). To verify the efficiency of banana pith it was compared to alum which showed comparable efficiency (pith 90% vs alum 95%). The study also revealed this natural coagulant's impact on the final pH was negligible, with a remarkable reduction in TOC. The study's notable reduced turbidity levels suggest that banana pith, as a natural coagulant, has the potential to serve as a feasible sustainable alternative to alum for water treatment purposes.

Keywords
Turbidity, Shoot system, Natural Coagulant, Pottery clay soil, Talaiya soil

1. Introduction

Ensuring the safety and quality of drinking water is crucial for protecting public health. Different techniques are utilized to ensure that drinking water is safe and appealing for consumption, and the selection of the appropriate method is dependent on the properties of the water source. When dealing with surface water, a major challenge is the considerable fluctuation in turbidity levels across different seasons. The accessibility of clean and affordable portable water has become a major concern, as the use of chemical coagulants in conventional water treatment methods is costly due to the expense of chemicals and managing the resulting sludge[1]. Water with high levels of suspended and colloidal particles increases water turbidity and poses a risk for transmitting pathogens. As a result, it is crucial to remove turbidity during water treatment. This can be achieved through the cost-effective and straightforward processes of coagulation and flocculation, which help to remove suspended particles and improve water quality. Moreover, the utilization of metal ions as coagulants in chemical-based processes has negative effects on human health [2].

Turbidity in water results from the presence of suspended particles, including small inorganic and organic matter such as clay, silt, algae, plankton, dissolved organic compounds, or other microscopic organisms. Measuring the turbidity of water serves as an indicator of possible contamination of water bodies. High levels of turbidity in drinking water can be unattractive and cause health risks. Turbidity, itself is not an indicator of health risk but studies show it can create a suitable environment for pathogens to thrive and reproduce in the water, potentially leading to waterborne diseases[3].

To remove turbidity in water, coagulation is the process that works by destabilizing and aggregating particles in water to form larger flocs that can be more easily removed by settling or filtration. Conventionally, chemical based coagulants such as alum (aluminum sulfate) and poly-aluminum chloride (PAC) have been widely used for this purpose in water treatment plants. However, nowadays concerns are raised about the potential health and environmental impacts of these chemical coagulants[4]. In response, researchers have explored many alternative coagulation agents, including plant-based materials. These plant-based coagulants typically contain natural polymers such as tannins, lignin, and polysaccharides that help to bind together suspended particles in water. Additionally, they are generally considered to be safer and more environmentally friendly and sustainable alternatives, as they are biodegradable and non-toxic. Overall, plant-based coagulants offer a promising approach for turbidity removal in water treatment, particularly in those regions where access to chemical coagulants may be limited or where environmental and health concerns are given priority[5].Hence, this study is conducted to determine the effectiveness one of such alternative approach using the banana shoot system as a natural coagulant as it is reported to contain various bioactive compounds, such as tannins and phenolic compounds, that possess coagulant properties[6].

2. Literature Review

Aluminum sulfate and ferric chloride are widely utilized in potable water purification because they are effective at removing impurities and contaminants from water. However, the production of these coagulants involves the mining and transformation of raw materials, which can be non-sustainable and thus have negative environmental and health impacts. Furthermore, the sludge generated during the water treatment process creates a different issue. It can be costly to dispose of, and can also have negative environmental impacts if not handled in a proper way[7]. As a result, there has been increasing interest in developing alternative coagulants that are more sustainable and have lower environmental impacts. Natural coagulants derived from plant sources are one such alternative that has gained increased attention as an option to chemical coagulants in water treatment. Despite considerable investigation on natural coagulants, the exploration of local plant leaves as coagulant agents has been relatively restricted. Leaves are considered a viable option for water treatment as they contain active substances, including proteins and carbohydrates [3]. Moringa oleifera is a tropical plant that has been widely studied for its coagulation properties. Its seeds and leaves contain cationic proteins that can effectively coagulate suspended particles in water. Studies have reported that Moringa oleifera can reduce turbidity and total suspended solids (TSS) in water by up to 99%[4]. Jatropha curcas seeds have been found to have excellent coagulation properties, which makes them effective in removing turbidity from water. One such study found that Jatropha curcas seed extract was able to remove up to 99.4% of the turbidity from water samples[8].Okra, also known as ladyfinger,a vegetable that is rich in polysaccharides,are known to have coagulating properties. Studies have reported that okra extracts can effectively reduce turbidity and TSS in water by up to 80%.

Among many plants sources, the banana plant contain a high concentration of polyphenols[9]. This facts prompts that it can be used as a coagulant in water treatment processes. Polyphenols can bind with dissolved organic matter and other impurities in water, allowing them to be easily removed. Banana plants can be found to be cost-effectiveness, Environmental sustainability, health benefit. So it can be used in the replacement of chemical coagulant. Overall, banana plants have shown great potential as a natural coagulant in water treatment. Further research is needed to optimize the coagulating efficiency of banana plants and to assess their effectiveness in different water sources and under different conditions.

3. Methodology

The study work mainly focusses to find out which banana shoot system (leaves, pith or peel) in particular has maximum coagulant property. Thereby, estimation of optimum dose of banana for removal of turbidity of water in a laboratory set up. The study was conducted at the laboratory of Environmental Engineering, Pulchowk Campus, IOE.

3.1 Collection and Preparation of Banana leaves, peel and stem Powder

Banana leaves and stem were sourced from Kirtipur Municipality's rural areas, while banana peel were procured from a local fruit shop. The leaves were thoroughly cleaned with distilled water, then cut into 5 to 7 cm pieces. Some leaves were oven-dried at 60°C for 48 hours, and the rest at 100°C for the same duration. These were finely ground into powder after drying and sieved using a 30 micron sieve. Similarly, banana peels were washed and sliced into 1 to 1.5 cm pieces. After 48 hours of drying at 60°C, they were ground into a fine powder and sifted with a 30 micron sieve. Banana pith,underwent cleaning, cutting, and sun drying for two days. Once dried, the pieces were finely ground, and particles smaller than 30 microns were selected for subsequent tests.

3.2 Preparation of various Banana coagulant solution

A quantity of 20 grams of dried powder was mixed with 1 liter of distilled water. The mixture was stirred using a magnetic stirrer for 10 minutes at room temperature to extract coagulation-active components.

3.3 Preparation of synthetic water sample

For generating turbid water samples ranging from 0 to 200 NTU, two distinct materials were utilized: pottery clay soil obtained from a pottery shop, and talaiya soil from Kirtipur Municipality. Both soil types were finely ground and sieved through a 300 micron sieve to achieve the desired high turbidity range. Six beakers were employed, with each containing half a liter of clear tap water. To maintain uniform turbidity levels, an equal quantity of either pottery clay soil or talaiya soil was introduced to all beakers. Thorough mixing ensured consistent turbidity among all samples.

3.4 Coagulation Jar Test Experiment

To assess the effectiveness of each coagulant solution, jar tests were conducted. Synthetic water samples (500 ml) were placed in beakers and stirred at 100 rpm at a constant room temperature. Different solution doses (5ml, 10ml, 15ml, 20ml, 25ml, 30ml) were added to the beakers and mixed for 3 minutes. The mixing speed was then lowered to 40 rpm and maintained for 20 more minutes. The mixture was allowed to settle. After 30 minutes, clarified samples were collected from the top of the beakers, and their turbidity was measured in Nephelometric Turbidity Units (NTU) using a turbidimeter. Multiple samples were taken to analyze the impact of banana coagulant dosage. The initial pH of the water sample was recorded, and the final pH of the treated water was measured using a pH meter. Through these tests, the optimal dose of the banana coagulant solution was determined.

4. Results and Discussion

4.1 Effectiveness of the coagulant solution using banana leaves, peel and pith

Coagulant solutions derived from banana leaves(dried at temperatures of 60°C and 100°C) and banana peel underwent

testing, demonstrating a decrease in water turbidity across all cases. Among these options, the coagulant solution sourced from banana pith displayed the highest efficiency in reducing turbidity(Figure 1). Excessive drying of banana leaves diminishes their coagulation effectiveness, with superior coagulation properties observed at 60°C rather than 100°C. On the other hand, banana pith, which is abundant in polysaccharides[10], presents a promising best option for use as a coagulant. Consequently, subsequent research will be centered on examining the effectiveness of banana pith in different level of turbidity.

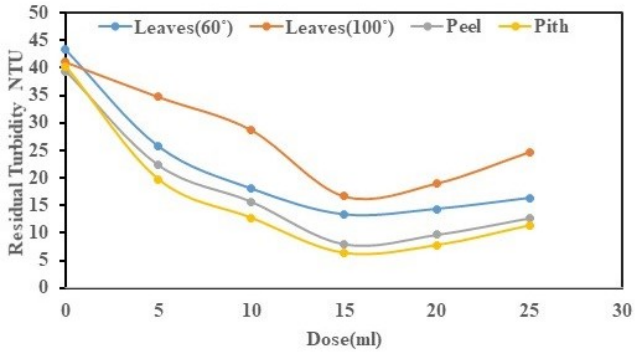

Figure 1: Screening of Various Banana shoot system for their potential coagulant property

4.2 Optimization of banana pith powder dose as a natural coagulant

The results showed that, as the initial turbidity of the water sample increases, a higher dose of coagulant is needed to achieve effective turbidity reduction and vice versa(Figure 2 and 3).For lower initial turbidity levels (0-50 NTU) in talaiya soil water samples, the optimal coagulant dose was found to be 15 ml at a 2% concentration. Conversely, for higher turbidity levels (200 NTU), the optimal dose increased to 25 ml. Similarly, in Pottery clay water samples, lower initial turbidity (0-50 NTU) necessitated an optimal coagulant dose of 10 ml at a 2% concentration, while higher turbidity levels (200 NTU) required a higher optimal dose of 25 ml. This underscores the importance of conducting sedimentation analysis at water sources before implementing water treatment procedures. Matching the coagulant dose to the initial turbidity levels is crucial for efficient turbidity reduction.

4.3 Alum vs Banana pith solution

The efficiency of Banana pith powder was comparable to alum in treating both talaiya soil and pottery clay soil water(Figure 4 and 5). When using Banana pith, the turbidity levels decreased to less than 10 NTU, which complies with the maximum limit set by NDQWS, even when the initial turbidity was as high as 75 NTU. Alum, on the other hand, also reduced turbidity to less than 10 NTU but couldn't meet the permissible limit for highly turbid water, which suggests that sources with exceptionally high initial turbidity should be considered unsuitable for use.

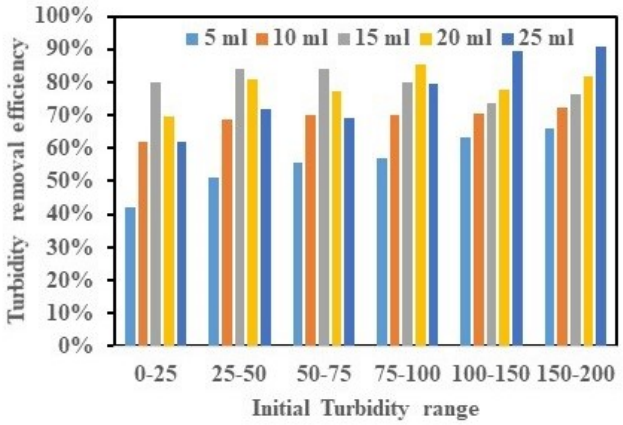

Figure 2: Turbidity removal efficiency of banana pith powder in talaiya soil water sample

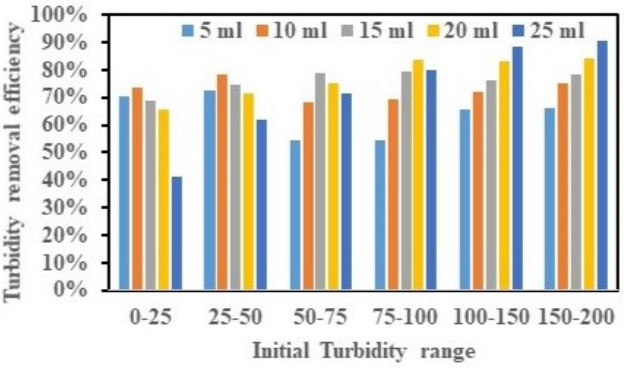

Figure 3: Turbidity removal efficiency of banana pith powder in pottery clay water sample

4.4 Variation of pH after treatment with coagulant

When using Banana pith powder to treat both talaiya soil water and pottery clay soil water samples, there was only a minor change in pH. However, when using alum for treatment, there was a more significant pH variation compared to the initial state, resulting in increased acidity(Figure 6 and 7).This highlights that the use of banana pith represents a cost-effective approach for reducing turbidity when compared to alum, as the latter necessitates additional steps for pH neutralization. Furthermore, the utilization of alum as a coagulant poses a risk of corrosion of transmission main.

4.5 Effect on Total Organic Carbon(TOC)

Utilizing plant-based coagulants can potentially foster microbial growth after treatment[11]. Thus, post-coagulation, the measurement of Total Organic Carbon (TOC) was conducted. Remarkably, the use of banana pith as a coagulant resulted in a drastic reduction of total organic carbon (TOC) as depicted in (Figure 8). The treatment of banana pith as a coagulant reduced the TOC of synthetic water (range 75-100 NTU) from 30mg/L to less than 3mg/L. This indicates that treated water had a decrease in the overall organic content, thereby possibly lowering the rate of microbial contamination. The coagulation process with banana pith powder effectively binds together organic particles, causing them to settle, and subsequently removing them from the water. This natural coagulant plays a crucial role in purifying water and

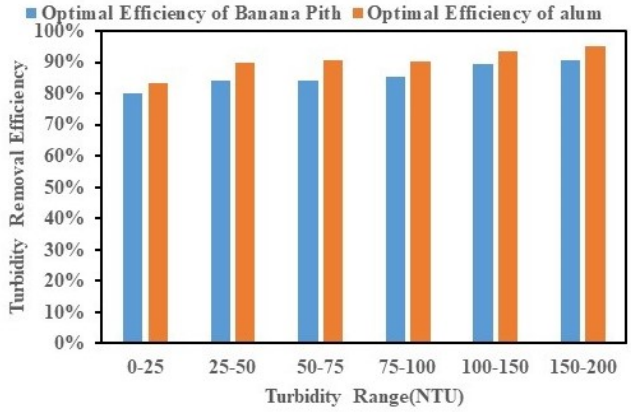

Figure 4: Efficiency Comparison of Alum vs Banana Powder solution for talaiya soil.

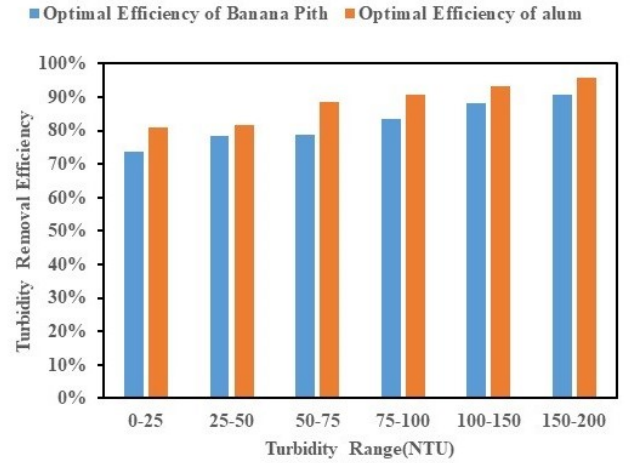

Figure 5: Efficiency Comparison of Alum vs Banana Powder solution for pottery clay soil.

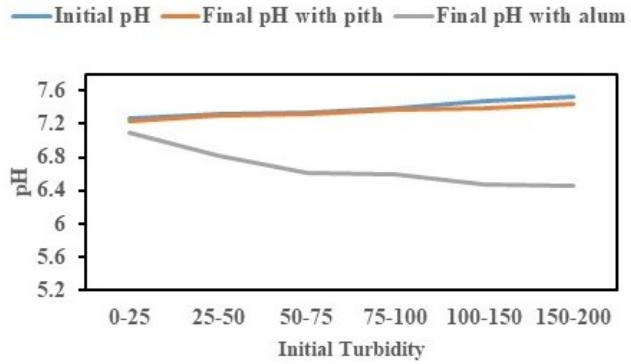

Figure 6: pH effect of Banana pith and Alum in talaiya soil

improving its quality by reducing the TOC levels.

5. Conclusion

In this research work, we have explored the waste parts from a banana plant into it's utilization as natural coagulant. From the study conducted and the results obtained, it can be concluded that:

1. Banana pith is the most effective coagulant solution among banana leaves, peel and pith.

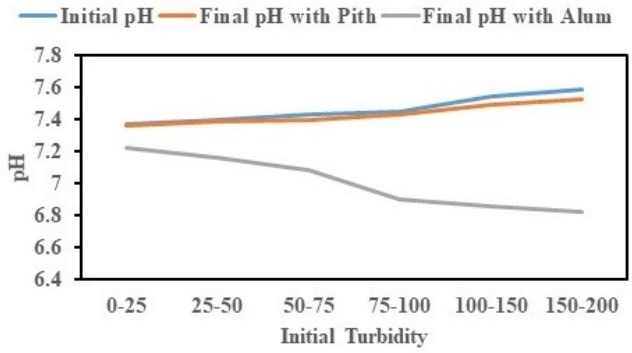

Figure 7: pH effect of Banana pith and Alum in pottery clay soil

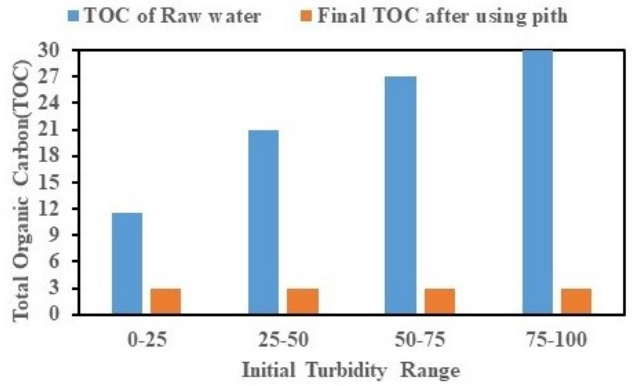

Figure 8: TOC effect on addition of banana pith powder

2. The turbidity removal efficiency of banana pith powder was comparable to alum. The maximum turbidity removal efficiency for banana pith is 90% whereas for alum is 95%.

3. There is minimal change in pH while treating with banana pith while the use of alum showed considerable pH variation compared to the initial pH of water.

4. Using banana pith powder as a coagulant results in a reduction of total organic carbon.

6. Limitations

1. Temperature variation may influence the result which is not considered in the study.

2. Study was limited artificially prepared turbid raw water.

Acknowledgments

The authors would like to acknowledge Asst. Prof. Mr. Rabin Maharjan, lab officers Mr. Amrit Acharya, and Ms. Manita Khatri for their continuous support during the laboratory work. We also extend gratitude towards Er. Reesav Dhakal, Er. Pujan Pradhan, and Mr. Ramesh Kathayat for their endless support during the entire period of this research.

References

[1] Ali H Ghawi. Using natural coagulant to remove turbidity and heavy metal from surface water treatment plant in iraq. *International Journal of Engineering Technology and Scientific Innovation*, 2(1):1851–2456, 2017.

[2] Arnulfo Antonio Tarón Dunoyer, Luis Enrique Guzmán Carrillo, and Rafael Emilio González Cuello. Removal of turbidity and color in domestic wastewater using aqueous seed extract of cassia fistula. *Revista Ambiente & Água*, 17, 2022.

[3] Azmi Ahmad, Siti Rozaimah Sheikh Abdullah, Hassimi Abu Hasan, Ahmad Razi Othman, and Nur 'Izzati Ismail. Potential of local plant leaves as natural coagulant for turbidity removal. *Environmental Science and Pollution Research*, 29(2):2579–2587, 2022.

[4] Mohammed Sulaiman, Daniel Andrawus Zhigila, Kabiru Mohammed, Danladi Mohammed Umar, Babale Aliyu, and Fazilah Abd Manan. Moringa oleifera seed as alternative natural coagulant for potential application in water treatment: A review. *J. Adv. Rev. Sci. Res*, 30(1):1–11, 2017.

[5] R Premkumar, S Rajesh, et al. Feasibility study on application of natural coagulants. In *Journal of Physics: Conference Series*, volume 2070, page 012186. IOP Publishing, 2021.

[6] NM Mokhtar, M Priyatharishini, and RA Kristanti. Study on the effectiveness of banana peel coagulant in turbidity reduction of synthetic wastewater. *International Journal of Engineering Technology and Sciences*, 6(1):82–90, 2019.

[7] Mussarat Saleem and Robert Thomas Bachmann. A contemporary review on plant-based coagulants for applications in water treatment. *Journal of Industrial and Engineering Chemistry*, 72:281–297, 2019.

[8] Zurina Z Abidin, Nur S Mohd Shamsudin, Norhafizah Madehi, and Shafreeza Sobri. Optimisation of a method to extract the active coagulant agent from jatropha curcas seeds for use in turbidity removal. *Industrial Crops and Products*, 41:319–323, 2013.

[9] Beatrice Kakoi, James Wambua Kaluli, Peter Ndiba, and George Thiong'o. Banana pith as a natural coagulant for polluted river water. *Ecological engineering*, 95:699–705, 2016.

[10] Mohapatra Debabandya, Mishra Sabyasachi, and Sutar Namrata. Banana and its by-product utilization: an overview. *J. Scient. Indust. Res*, 69:323–329, 2010.

[11] Mohammed Awad, Hongtao Wang, and Fengting Li. Weaknesses of moringa oleifera use in water treatment. *Int J Curr Res*, 5:1165–1167, 2013.