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Effectiveness of Powder Tamarind Seeds (*Tamarindus indica L.*) as a Natural Coagulant in the Treatment of Peat Water Turbidity

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Abstract. Peat water is one of the alternative water sources found in swamp areas and tropical rainforests. However, its use as a source of clean water has several limitations, as it generally has a low pH, a dark brown to blackish color due to the presence of humic and fulvic acids, and a high turbidity level. This study aims to evaluate the effectiveness of tamarind seeds (*Tamarindus indica* L.) as a natural coagulant in reducing the turbidity and color of peat water. The tamarind seeds were processed into powder with a particle size of 250 mesh. Coagulation was carried out with rapid mixing at 100 rpm for 5 minutes, followed by flocculation at 30 rpm for 30 minutes. The doses used varied: 0.5, 1, 1.5, and 2 g per 500 mL of peat water sample. The effectiveness of the coagulation-flocculation process was determined based on the parameters of turbidity reduction, TDS, light intensity, Sludge Volume Index (SVI), Sludge Mass (SM), and floc characteristics.

1 Introduction

Peat water is a water source that possesses unique characteristics, one of which is its high humic acid content. Humic acid is an organic compound formed through the decomposition of organic matter under anaerobic conditions, which commonly occurs in areas with peat soils [1]. This process takes place over thousands of years, during which the accumulation of partially decomposed organic material creates ideal conditions for the formation of humic acid. Humic acid significantly contributes to the physical and chemical properties of peat water, giving it a reddish-brown color and a low pH, typically ranging from 3 to 5 [2].

Tamarind (*Tamarindus indica*) is a type of fruit known for its sour taste. The tree that produces this fruit belongs to the legume family (Leguminosae). This species is the only member of the *Tamarindus* genus [3]. The fruit that is old, fully ripened, and dried is commonly referred to as *asam kawak*. Coagulation is a process that causes the destabilization of colloids in wastewater through the addition of chemicals (coagulants), which is then followed by the formation of larger particles (flocs) [4]. The aggregation of floc cores into larger flocs allows in wastewater through the addition of chemicals (coagulants), which is then followed by the formation of larger particles (flocs) [5]. The aggregation of floc cores into larger flocs allows these particles to settle [6]. The principle of coagulation explains that water contains solid particles that generally carry a negative electrical charge. These particles tend to repel each other, which keeps them stable in colloidal form within the water. To neutralize the negative charges on these solid particles, positively charged coagulants are added to the water, followed by rapid mixing [6].

2 Materials and Methods

2.1 Materials

Powder Tamarind seeds, 90% humic acid, $Fe(NO_3)_3 \cdot 9H_2O$, 99.99% NaOH, 37% HCl (pro analysis grade), 0.45 µm membrane filter paper, buffer solutions (pH 4, 7, and 10), weighing paper, petroleum jelly, and distilled water.

2.2 Preparation of tamarind seed samples

Tamarind seed powder was sieved using a 250-mesh sieve. It was then oven-dried at 105 °C for 2 hours. The resulting tamarind seed powder was stored in a desiccator and used as a natural coagulant.

2.3 Preparation of synthetic peat water samples

A 1000 mg/L standard humic acid solution was prepared by dissolving 1 g of humic acid and 4 g of NaOH in 1 L of distilled water, then stirred magnetically for 24 hours. A volume of 250 mL of the standard solution was diluted with distilled water in a 500 mL volumetric flask to obtain a working solution of 500 mg/L. From the working solution, 0.25 g was taken for analysis [7]. The pH of the peat water was then adjusted to 5 using 0.1 M NaOH or 0.1 M HCl solution.

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2.4 Coagulation-flocculation process

The remediation of peat water was carried out using the coagulation-flocculation method with a jar test apparatus. A volume of 250 mL of peat water was placed into a beaker, and tamarind seed powder was added at doses of 0.5, 1, 1.5, and 2 g. The solution was rapidly stirred at 100 rpm for 5 minutes, followed by slow stirring at 30 rpm for 30 minutes. The coagulation-flocculation results were allowed to settle for 24 hours in an Imhoff cone and then filtered using Whatman No. 42 filter paper.

2.5 Floc image capture

Flocs were taken 10 minutes after the coagulation-flocculation process ended, and images were captured directly from the aquarium. The formed flocs were then observed using a calibrated digital microscope (AF4515-FIT Dino-Lite Edge, Anmo Electronics Corporation, Taiwan) with a magnification of 25.9×. The distance between the sample aquarium and the digital microscope was set between 1 to 2 cm, as shown in Fig. 1.

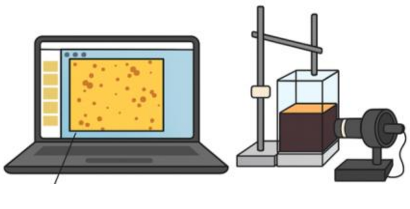


Fig 1. Digital Microscope Setup

Floc measurements were performed using the Dino-Capture 2.0 software application integrated with the Dino-Lite digital microscope.

2.6 Calculation of equivalent floc diameter

Flocs The equivalent diameter can be calculated using Equation 1, where d_{eq} is the equivalent diameter (mm), A is the area (mm²), and π\piπ is 3,14 [8].

$$d_{eq} = 2\sqrt{\frac{A}{\pi}} \quad (1)$$

Referring to the British Standard method for microscopic counting, the number of floc particles measured must be more than 625 particles [8]. The floc size distribution is created by plotting the equivalent floc diameter on the x-axis and the number of flocs on the y-axis.

2.7 Sludge Volume Index (SVI)

A Peat water samples after the coagulation-flocculation treatment were allowed to settle for 1 hour to form sludge. The volume of the formed sludge was then measured in an Imhoff [9]. The SVI measurement was carried out using the following equation:

$$SVI = \frac{Volume\ of\ settled\ sludge\ \left(\frac{mL}{l}\right)\times 1000}{Suspended\ sludge\ \left(\frac{mg}{L}\right)} \quad (2)$$

2.8 Sludge Mass (%)

A The treated sample was filtered using a vacuum pump and Buchner funnel with Whatman No. 42 filter paper. After filtration, the wet sludge was weighed, then dried in an oven at 60°C for 30 minutes. It was then placed in a desiccator for 15 minutes and weighed to obtain the dry weight. The sludge mass (SM) measurement was carried out using the following equation:

$$SM\ (\%) = \frac{Wet\ sludge\ (mg) - Dry\ sludge\ (mg)\ x\ 100}{Wet\ sludge\ (mg)} \quad (3)$$

3 Result and Discussion

3.1 Characteristics of peat water and clean water

3.2 Characterization of biocoagulants using FTIR, proximate, and SEM-EDX analysis

The OH functional group absorbs infrared radiation in the wavenumber range of 3000–3600 cm⁻¹. The O–H stretching is indicated by an absorption peak at 3430 cm⁻¹. The C–O functional group can be observed at a wavenumber of 1246 cm⁻¹, while the glycosidic bond is indicated at 899 cm⁻¹. The C=O functional group appears at 1739 cm⁻¹. Furthermore, the protein-bound C=O group is shown by an absorption at 1627 cm⁻¹, followed by the N–H group at 1517 cm⁻¹. Lastly, the C–H functional group is indicated by absorption peaks at 3430 cm⁻¹ and 2920 cm⁻¹.

Based on the results of proximate analysis, tamarind seeds contain 2.59% fat. The fat content in natural coagulants can affect their performance, as fat may inhibit floc formation. The moisture content in tamarind seeds is 6.6%.

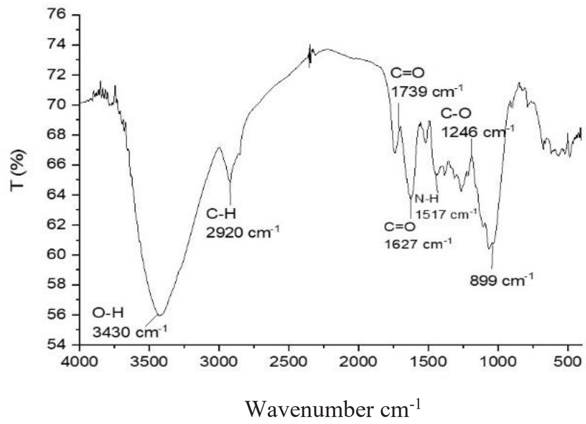


Fig 2. FTIR Spectrum of Tamarind Seeds

A high moisture content can accelerate mold growth, which in turn may lead to faster spoilage. The ash content in tamarind seeds is 3.7%. Ash content indicates the amount of inorganic minerals present in the seeds, which can affect the Total Dissolved Solids (TDS) value in water

Table 1. Proximate Composition Analysis (%)

Water %	Ash content %	Carbohydrate %	Protein %	Fat %
6,6	3,7	84,6	2,4	2,56

In this study, EDX analysis was used to determine the elemental composition of tamarind seed powder. The results of this analysis are important because the elemental composition can provide insights into the potential active compounds or minerals involved in the coagulation–flocculation mechanism.

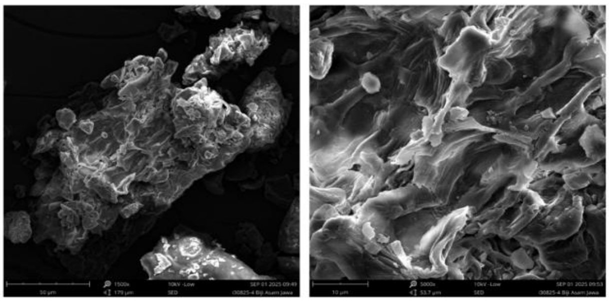
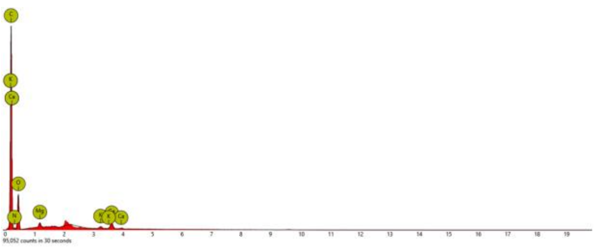


Fig 3. SEM Images of Tamarind Seed Powder at 1500× and 5000× Magnifications

SEM analysis revealed that the surface of tamarind seed powder exhibits an uneven, layered, and porous morphology. This structure increases the specific surface area and supports the adsorption of colloidal particles. At 1500× and 5000× magnifications, cavities, cracks, and fine pores are visible, which facilitate physical interactions between the coagulant particles and colloids during the coagulation process.

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	69.58	62.55
8	O	Oxygen	24.05	28.80
7	N	Nitrogen	5.10	5.34
20	Ca	Calcium	0.66	1.97
12	Mg	Magnesium	0.43	0.78
19	K	Potassium	0.19	0.56



Disabled elements: Au, B, Nb

Fig. 4 Elemental Composition of Tamarind Seed Powder and EDX Spectrum

EDX analysis showed that tamarind seed powder is primarily composed of carbon (C), oxygen (O), and nitrogen (N), with minor amounts of mineral elements such as calcium (Ca), magnesium (Mg), and potassium (K). The organic elements contribute to the formation of functional groups like –OH, –COOH, and $-NH_2$, which support the coagulation–flocculation process, while the mineral elements act as factors for neutralizing colloidal charges.

3.3 Floc characteristics at various dosages

The floc size distribution resulting from the coagulation–flocculation process using tamarind seed powder showed significant variation at each coagulant dosage applied. Increasing the coagulant dosage affected the number, size, and morphology of the flocs formed during the peat water treatment process.

Based on the graph of floc count distribution versus equivalent diameter at dosages of 0.5, 1, 1.5, and 2 g, as well as microscopic observations, it was found that increasing the dosage resulted in significant changes in floc shape and size. Each dosage variation produced flocs with different characteristics in terms of density, homogeneity, and sediment stability.

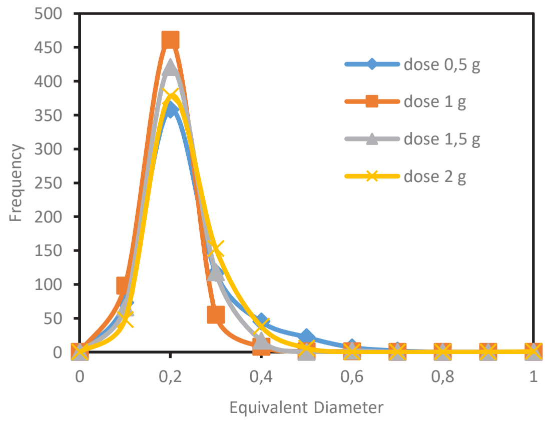


Fig 5. Distribution of Floc Count and Equivalent Diameter at Various Dosages

Fig. 5 and Fig. 6 shows the floc count distribution and floc size distribution respectively, indicate a peak at a diameter of 0.2 mm for all dosages of tamarind seed powder. The highest frequency was observed at 1 g (461 particles), followed by 1.5 g (421), 2 g (378), and 0.5 g (358). The 0.5 g dosage resulted in a broader distribution extending up to 0.6 mm, indicating slower and more varied floc formation. The 1 g dosage produced the most concentrated distribution around 0.2 mm and the most uniform flocs, demonstrating the most efficient coagulation–flocculation process. At 1.5 g, some flocs aggregated to sizes greater than 0.3 mm, whereas the 2 g dosage produced larger flocs but with a decreased total count due to overdosing. Overall, the 1 g dosage yielded the most uniform and highest number of flocs, indicating optimal efficiency [11].

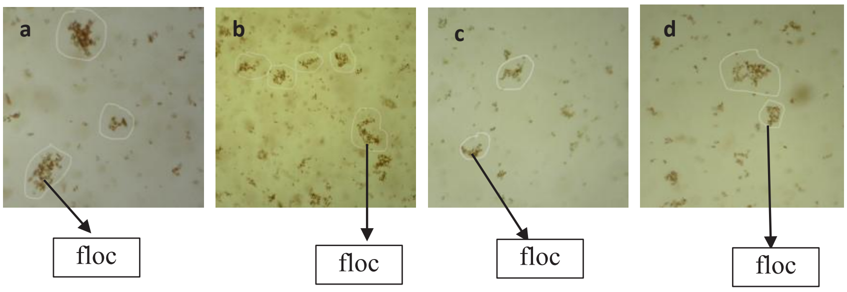


Fig 6. Images of flocs formed at dosages of 0.5 g (a), 1 g (b), 1.5 g (c), and 2 g (d).

Microscopic images of the flocs (Figure 6) show structural differences at each dosage of tamarind seed powder. The 0.5 g dosage produced the densest, largest, and most compact flocs, indicating optimal bridging of colloidal particles. At 1 g, flocs were still abundant but less dense. Dosages of 1.5 g and 2 g exhibited smaller, thinner, and more dispersed flocs, suggesting an excess of coagulant that triggered particle restabilization, thereby reducing the effectiveness of the coagulation process.

3.4 Effect of solution pH and point of zero charge (pzc) on the coagulation-flocculation process

The determination of the Point of Zero Charge (PZC) aims to identify the pH at which the surface of the natural coagulant, tamarind seed powder, is electrically neutral—meaning it carries neither a positive nor negative charge. In this study, the PZC was determined using the pH drift method with 50 mL of 0.01 M NaCl solution and 0.5 grams of tamarind seed powder suspended and shaken for 48 hours. The PZC results provide important information about the optimum pH condition at which the coagulant operates most effectively in charge neutralization and floc formation during the coagulation–flocculation process
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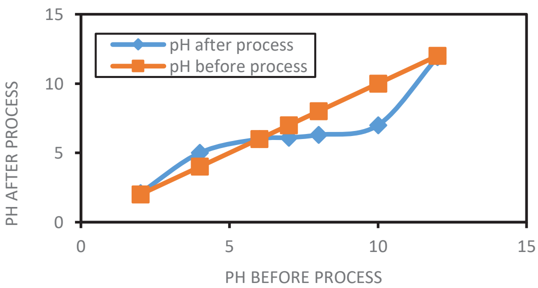

Fig 7. Comparison of Initial pH, PZC, and Final pH of Tamarind Seed

Figure 7 shows that the final pH values tend to stabilize within the initial pH range of 6 to 8. At an initial pH of 6, the final pH was recorded at 5.7 and increased to 6 at an initial pH of 7. After the initial pH exceeded 7, the difference between the initial and final pH values increased again. The intersection point between the initial and final pH curves is approximately at pH 6.1, which is interpreted as the point of zero charge (PZC) of the tamarind seed powder coagulant.

The PZC value of 6.1 indicates that at pH below 6, the coagulant surface carries a positive charge, enabling electrostatic interactions with negatively charged colloidal particles, such as humic acid present in peat water. Conversely, at pH above 7, the coagulant surface becomes negatively charged, causing repulsive forces between similarly charged particles. This condition reduces the effectiveness of the coagulation process.

Understanding the PZC value is important because it determines the effectiveness of surface interactions between the coagulant and dispersed particles in water. In this study, the coagulation–flocculation process was conducted at three pH conditions representing different surface charge characteristics: pH 3 (below the PZC), pH 6.1 (at the PZC), and pH 10 (above the PZC).

Figures 8(a), 6(b), and 6(c) sequentially show the floc shapes formed under each respective pH condition. The comparison of floc morphology at these three pH variations provides insight into the influence of surface charge on the formation and stability of flocs during the coagulation–flocculation process using tamarind seed powder.

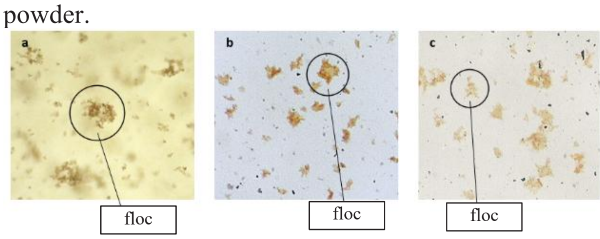

Fig 8. Images of flocs formed at pH 3 (a), at the PZC (b), and at pH 10 (c)

Figure 8(a) shows that the flocs at pH 3 appear dense, compact, and tightly packed because the coagulation mechanism is dominated by charge neutralization due to high protonation, causing strong aggregation of negatively charged colloidal particles.

Figure 8(b) shows that the flocs at the PZC (pH 6.1) appear less dense and somewhat loose. The coagulation mechanism still involves charge neutralization, but the inter-particle bonding is not as strong as at pH 3, although it still results in reasonably good sedimentation.

Figure 8(c) shows that the flocs at pH 10 appear loose, branched, and non-compact. This structure indicates that the coagulation mechanism is dominated by bridging between particles, making the flocs more prone to breakage and difficult to settle stably. Overall, the most stable flocs form at pH 3, moderately stable flocs form at pH 6.1, and unstable flocs form at pH 10.

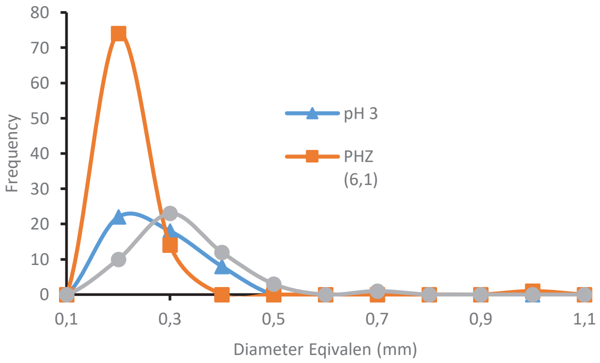

Fig 9. Floc Size Distribution at Various pH Levels

Figure 9 shows that the floc size distribution varies under different pH conditions. At pH 3, the flocs are dominated by equivalent diameters of 0.2–0.3 mm, with the highest counts being 22 flocs at 0.2 mm and 18 flocs at 0.3 mm. The flocs formed are small to medium-sized but stable, as the coagulation mechanism is dominated by charge neutralization due to high protonation.

At the PZC (pH 6.1), the floc distribution is concentrated at a diameter of 0.2 mm with a count reaching 74 flocs, making it the highest number of flocs compared to other conditions. This sharp and homogeneous distribution indicates that the charge neutralization mechanism is most dominant and efficient at the point of zero charge pH.

At pH 10, the floc size distribution is more spread out, with a peak at 0.3 mm diameter (23 flocs) and a significant number at 0.4 mm (12 flocs), with some flocs even reaching sizes up to 1.0 mm, although few in number. This condition indicates that the bridging mechanism between particles is more dominant, producing larger but fewer and less stable flocs.
Overall, low pH produces many small flocs, neutral pH yields the highest number of small and homogeneous flocs, while alkaline pH results in fewer but larger flocs. These differences confirm that the coagulation mechanism is influenced by pH conditions, with charge neutralization dominating at low to neutral pH and bridging prevailing at alkaline pH.

3.5 Effect of solution pH and point of zero charge (pzc) on peat water

Table 2 shows that the coagulation–flocculation process using 0.5 g of tamarind seed powder can shift the final pH of peat water toward a more neutral condition. At an initial pH of 3, the final pH increased to 3.9; at the PZC (pH 6.1), the pH remained stable; and at pH 10, the final pH decreased to 6.7. This confirms the ability of the natural coagulant to stabilize the solution pH.

The effectiveness of the process is also reflected in the reduction of turbidity and TDS, as well as the improvement in water clarity. At pH 3, turbidity decreased by 98.4% and TDS decreased by 42.32%. At the PZC pH, turbidity decreased by 98.45% and TDS by 41.02%. Meanwhile, at pH 10, turbidity decreased by 95.5% and TDS by 24.06%.

These results indicate that acidic (pH 3) and neutral (PZC pH) conditions are more effective than basic conditions. The high effectiveness at low pH is attributed to the protonation of the coagulant's functional groups, which increases the positive surface charge. Meanwhile, at the PZC, particle interactions occur optimally due to the neutral surface potential. Conversely, the effectiveness decreases at pH 10 because deprotonation reduces the number of positive charges and decreases the stability of the flocs.

Overall, this study demonstrates that tamarind seed powder is effective as a natural coagulant for reducing turbidity and total dissolved solids (TDS) in peat water, with optimal performance under acidic and neutral conditions.

Table 2. Characteristics of peat water after coagulation–flocculation at different pH conditions

Control pH	Final pH	Turbidity (NTU)	TDS (mg/L)	Light Intensity (Lux)
3	3,9	1,33	740	1391
PHZ (6,1)	6,1	1,26	816	1325
10	6,7	3,34	802	733,7

3.6 Effect of coagulant dosage on peat water quality

The coagulant dosage is a crucial factor in the coagulation–flocculation process, as it determines the effectiveness of floc formation [7]. A dosage that is too low is unable to bind all particles, whereas an excessively high dosage may produce large flocs that are difficult to settle [4]. In this study, the optimum dosage of tamarind seed powder for clarifying 500 ppm synthetic peat water was 0.5 g. As the dosage increased, the color change of the peat water became more noticeable. The initial peat water with a pH of 5 experienced changes after the coagulation–flocculation treatment with various dosages of 0.5 g, 1 g, 1.5 g, and 2 g. The pH values changed to 5.4, 5.1, 4.7, and 4.6, respectively. These changes indicate that the amount of coagulant influences the final pH of the solution. At dosages of 0.5 g and 1 g, the pH increased compared to the initial condition. The increase in pH is presumed to result from a neutralization reaction between charged compounds in the seed powder, such as proteins or basic components, and organic acids (humic and fulvic acids) present in the peat water [2].

Table 3. Comparison of Various Dosages

Dose (g)	pH	Turbidity (NTU)	TDS (mg/L)	Light Intensity (Lux)	Visual

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Initial	5	109	1248	87	
0.5	5,5	0,31	978	1742	
1	5,1	0,47	996	1582	
1.5	4,7	0,51	1050	1532	
2	4,6	0,66	1058	1493	

Coagulation using tamarind seed powder significantly reduced the turbidity of peat water. The initial turbidity of 109 NTU decreased to 0.31 NTU, representing a 99.72% reduction at a dosage of 0.5 g; 0.47 NTU with a 99.56% reduction at 1 g; 0.51 NTU with a 99.52% reduction at 1.5 g; and 0.66 NTU with a 99.43% reduction at 2 g. The 0.5 g dosage provided the most optimal result. The decrease in turbidity was accompanied by an increase in light intensity, indicating a lower concentration of colloidal particles and improved water clarity.

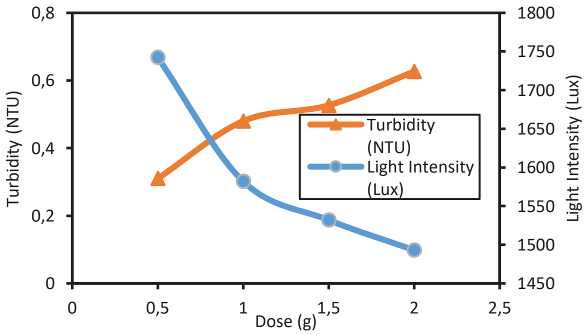

Fig 10. Effect of Coagulant Dosage on Turbidity (NTU) and Light Intensity (Lux) in Peat Water

Figure 10 shows that the decrease in turbidity is directly proportional to the increase in light intensity, where low turbidity values correspond to higher light intensity. The optimum dosage is 0.5 grams, which yields the lowest turbidity and the highest light intensity values.

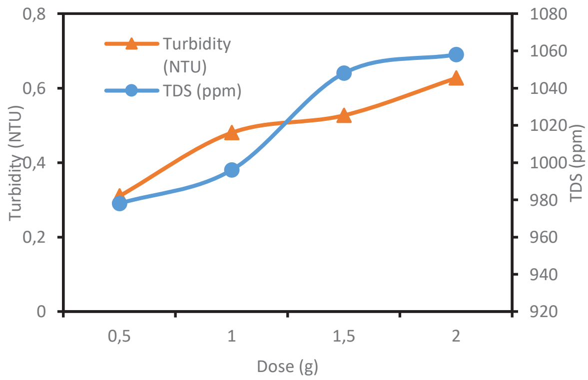

Fig. 11 Effect of Coagulant Dosage on TDS and Turbidity in Peat Water

The graph illustrating the relationship between coagulant dosage and TDS and turbidity values shows that the coagulation-flocculation process in synthetic peat water has varying effects depending on the dosage used. Based on the data, the initial TDS value of 1248 ppm significantly decreased after the addition of the coagulant. At a dosage of 0.5 g, TDS decreased to 978 ppm, indicating the effectiveness of the coagulant in binding and precipitating dissolved substances. However, with increasing dosages of 1 g, 1.5 g, and 2 g, the TDS values rose again to 996 ppm, 1048 ppm, and 1058 ppm, respectively. This increase in TDS is attributed to excess coagulant that remains unreacted and contributes to the total dissolved solids in the solution.

The turbidity values show an increasing trend with increasing coagulant dosage. At a dosage of 0.5 g, the lowest turbidity was 0.31 NTU, which then increased to 0.48 NTU at 1 g, 0.53 NTU at 1.5 g, and reached 0.63

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NTU at 2 g. This increase in turbidity is likely caused by the formation of unstable or broken flocs, as well as the presence of coagulant particles that do not fully aggregate and remain suspended in the solution. Excessive dosage can lead to particle restabilization, a condition in which charged particles become stable and dispersed again, thereby increasing water turbidity.

The relationship between TDS and turbidity values in the coagulation-flocculation process of synthetic peat water shows a generally proportional pattern. Based on the graph, at a coagulant dosage of 0.5 grams, both TDS and turbidity reached their lowest values, at 978 ppm and 0.31 NTU, respectively.

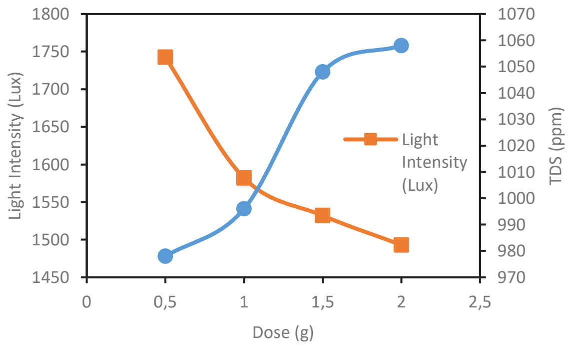


Fig 12. Effect of Coagulant Dosage on Light Intensity and TDS in Peat Water

Variations in the dosage of tamarind seed powder affected the TDS and light intensity values of peat water. A dosage of 0.5 g resulted in the lowest TDS (978 ppm) and the highest light intensity (1742 Lux), indicating optimal clarity. Increasing the dosage to 1 g led to a rise in TDS (996 ppm) and a decrease in light intensity (1582 Lux), due to the formation of colloidal particles. At 1.5 g, TDS increased to 1048 ppm, but light intensity slightly improved (1532 Lux), possibly due to partial flocculation of particles. A dosage of 2 g resulted in the highest TDS (1058 ppm) and the lowest light intensity (1493 Lux), likely due to excess coagulant. Overall, TDS and light intensity exhibited an inverse relationship, highlighting the importance of an optimal coagulant dosage for effective water clarification.

3.7 Analysis of Fe and TOC content at the optimum coagulant dosage

Laboratory analysis of 0.5 g of tamarind seed powder showed a TOC value of 41.728 mg/L and an Fe concentration of 2.7099 ± 0.091 mg/L. The high TOC value indicates the presence of organic compounds (carbohydrates, proteins, and tannins) that contribute to coagulation through –OH and –COOH functional groups, while the Fe content originates from natural minerals that act as natural coagulants by forming interparticle bonds. These findings confirm that tamarind seed powder releases organic and mineral compounds that support the coagulation–flocculation mechanism; however, dosage optimization is still required to ensure that the dissolved substances do not affect the quality of the treated water.

Table 4. Analysis Results of TOC and Fe Content in Tamarind Seed Powder Solution After the Coagulation–Flocculation Process at the Optimum Dosage of 0,5 g

No	Sample	Parameter	Test Result	Unit	Method
1	Tamarind seed powder solution (0,5g) after process	TC-IC	41,728	mg/L	Total Organic Carbon
2	Tamarind seed powder solution (0,5g) after process	Fe	2,7099	mg/L	Atomic Absorption Spectrophotometer

3.8 Analysis of Fe and TOC content at the optimum coagulant dosage

SEM-EDX analysis was used to observe the surface morphology and elemental distribution of tamarind seed powder at the optimum dosage, while FTIR analysis was employed to identify changes in functional groups involved in the coagulation flocculation process.

Fig 13. Sludge obtained at the optimum dosage analyzed using SEM-EDX and FTIR

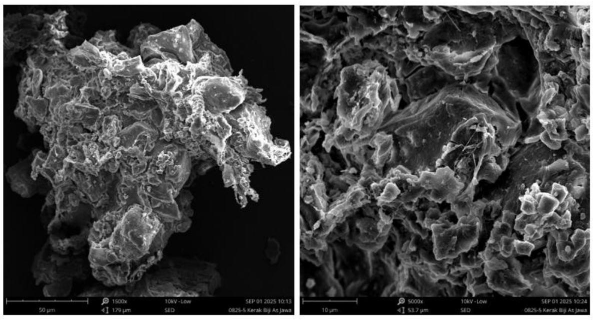
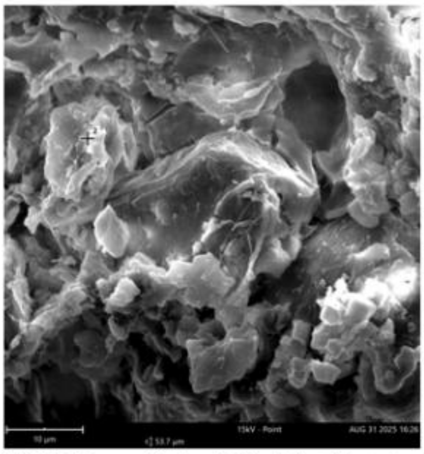


Fig 14. Surface Morphology of Sludge at the Optimum Dosage (0.5 g) of Tamarind Seed Coagulant (SEM)

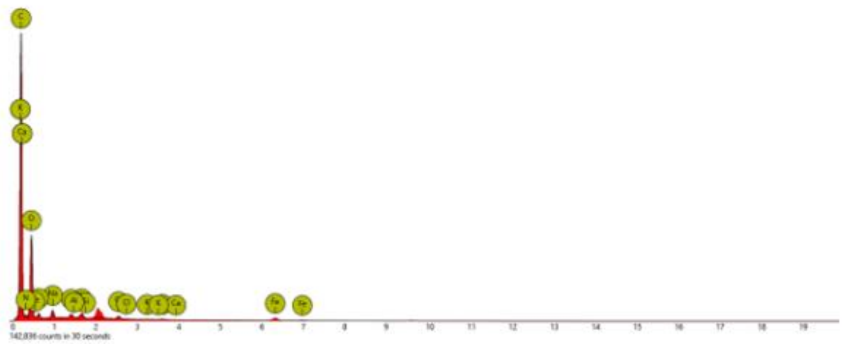
The sludge formed at the optimum dosage of 0.5 g tamarind seed powder was selected as the sample because it represents the best condition, where the resulting flocs exhibit high density and stability, making them more compact and easier to settle. The SEM results in Figure 14 (1500×) show that the sludge surface has a rough, layered, and porous morphology, with coagulant particles adhering to the colloids to form large aggregates.

This layered structure indicates strong interactions between the organic components of tamarind seeds and the colloidal particles. At a magnification of 5000×, small pores and a multilayered surface are observed, which increase the adsorption area for both colloidal particles and metal ions. This condition enhances the effectiveness of the coagulation–flocculation mechanism at the optimum dosage of 0.5g.



Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	64.68	57.07
8	O	Oxygen	28.30	33.26
7	N	Nitrogen	5.43	5.59
26	Fe	Iron	0.44	1.82
11	Na	Sodium	0.60	1.02
14	Si	Silicon	0.18	0.37
13	Al	Aluminium	0.17	0.33
17	Cl	Chlorine	0.12	0.30
20	Ca	Calcium	0.06	0.16
19	K	Potassium	0.03	0.08

FOV: 53.7 µm, Mode: 15kV - Point, Detector: SED, Time: AUG 31 2025 16:26



Disabled elements: Au, B, Nb, Te, Zr

Fig 15. Elemental Composition of Sludge at the Optimum Dosage (0.5 g) of Tamarind Seed Coagulant (EDX)

EDX analysis of the sludge at the optimum dosage of 0.5 g revealed a predominance of carbon (64.68%), oxygen (28.30%), and nitrogen (5.43%). The high carbon content indicates the dominance of organic compounds from tamarind seeds, while oxygen confirms the presence of –OH and –COOH groups, and nitrogen reflects the role of $–NH_2$ groups in the bonding mechanism. Additionally, minerals such as Fe, Na, Si, Al, Cl, Ca, and K were detected in small amounts and contribute to the neutralization of colloidal charges.

Overall, the SEM-EDX results show that the sludge at a 0.5 g dosage exhibits a rough, layered, and porous morphology with a dominant organic elemental composition alongside supporting minerals. These conditions reinforce the role of tamarind seeds as an effective natural coagulant through adsorption, charge neutralization, and the formation of stable flocs.

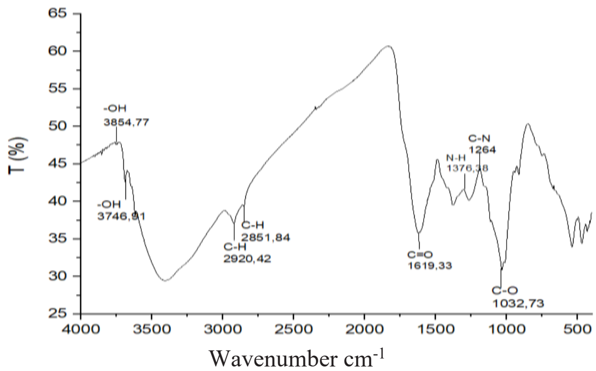


Fig 16. FTIR Analysis of Sludge at the Optimum Dosage

The FTIR results in Figure 16 for the sludge at the optimum dosage of 0.5 g show characteristic wavenumbers of carbohydrates and proteins. The wavenumbers at 3854–3619 cm⁻¹ correspond to –OH stretching vibrations, 2920–2851 cm⁻¹ indicate C–H stretching, and 1264–1032 cm⁻¹ represent C–O stretching, all of which are characteristic of carbohydrates in tamarind seeds. Additionally, the wavenumbers at 1619 cm⁻¹ (C=O stretching, Amide I), 1376 cm⁻¹ (N–H bending, Amide II), and 1264 cm⁻¹ (combined C–N stretching and N–H bending, Amide III) indicate the presence of proteins. These findings confirm that the sludge at a 0.5 g dosage contains organic compounds, specifically carbohydrates and proteins, which play roles in adsorption, interparticle interactions, and floc formation during the coagulation–flocculation process.

3.9 Evaluation of natural coagulant performance

Coagulant efficiency can be expressed through sludge mass (SM) and sludge volume index (SVI). SVI is a method used to evaluate sludge settling behavior. An SVI value below 80 mL/g indicates excellent settling characteristics, a value between 100–150 mL/g indicates good settling, while an SVI value above 150 mL/g suggests poor settling with slow sedimentation [12].

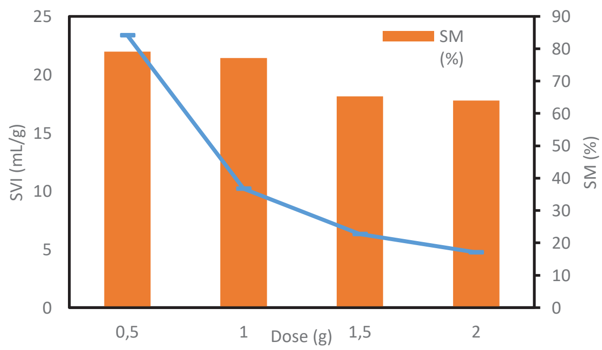


Fig 17. SVI (ml/g) vs SM (%)

The efficiency of tamarind seed coagulant was evaluated using the Sludge Volume Index (SVI) and Sludge Mass (SM). The SVI values decreased with increasing dosage, from 23.36 mL/g (0.5 g) to 10.21 mL/g (1 g) and 4.74 mL/g (2 g), all well below the 80 mL/g threshold [1]. indicating excellent settling performance. The SM values also decreased from 79.12% (0.5 g) to 63.99% (2 g), demonstrating reduced sludge volume with the formation of denser and more easily settled flocs. Dosages of 1.5–2 g resulted in the lowest SVI and most efficient SM, confirming the potential of tamarind seed as an eco-friendly natural coagulant for peat water treatment.

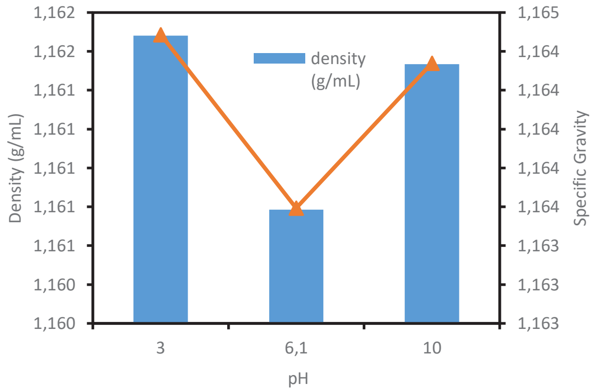


Fig 18. SVI (mL/g) vs. SM (%) at Various pH Levels of Tamarind Seed Powder

Figure 18 shows that at the optimum dosage of 0.5 g tamarind seed powder, SVI and SM values are influenced by pH variation. At pH 3, the SVI was 24.108 mL/g and SM was 79.26%, indicating the formation of large but less dense flocs. At the PZC (pH 6.1), the SVI decreased to 9.16 mL/g and SM increased to 87.74%, indicating denser and more stable flocs, resulting in more effective sedimentation. At pH 10, the SVI further decreased to 7.91 mL/g and SM increased to 91.86%, showing that the flocs became even denser and easier to settle.

4 Conclusion

Tamarind seed has been proven effective as a natural coagulant in peat water treatment. An optimum dosage of 0.5 grams significantly reduced turbidity and TDS, increased light intensity, and produced large, dense flocs. The low SVI values across all dosages indicate excellent settling ability, while the decreasing sludge mass values demonstrate efficient particle binding. Therefore, tamarind seed shows great potential as an eco-friendly alternative coagulant.

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