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RESEARCH ARTICLE

Exploring plant-based coagulants for turbidity reduction: case study of *Pandanus amaryllifolius* and coconut husk

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ABSTRACT

Coagulants are essential in water treatment processes particularly in coagulation and flocculation for reducing suspended solids and improving water clarification. The purpose of this study is to investigate the effectiveness of plant-based coagulants from coconut husk and pandan leaves in reducing turbidity of river water. The study used jar test to determine the optimal coagulant dose and solution pH for coconut husk and pandan leaves coagulants in reducing river water turbidity with alum used as a benchmark for comparison. In addition, a comparison between these plant-based coagulants and alum was made to see the potential of the coagulants. Scanning electron microscopy (SEM) was employed to observe the morphology of the plant-based coagulants while phytochemical tests confirmed the presence of tannins and flavonoids through colorimetric observation. Results indicated that pandan leaves coagulants achieved up to 90% turbidity removal of river water at an optimal dose of 40 mg/L and pH 9, whereas coconut husk coagulant reached 60% removal at 10 mg/L and pH 4. SEM analysis revealed fibrous structures with rough surface textures, suggesting good potential for particle adsorption. Overall, both plant-based coagulants demonstrated promising performance in turbidity reduction, supporting their potential as sustainable alternatives to conventional chemical coagulants.

INTRODUCTION

Turbidity in water is primarily caused by the presence of suspended solids. As the concentration of these particles increases, water clarity diminishes, making submerged objects less visible. Turbidity is a critical parameter in drinking water quality, as microorganisms can attach to suspended particles, thereby reducing the efficacy of disinfection processes. Consequently, effective removal of colloidal particles is essential not only to improve the aesthetic quality of drinking water but also to ensure its microbiological safety.

Turbidity is commonly measured using nephelometric methods, with results expressed in Nephelometric Turbidity Units (NTU). Elevated turbidity levels can also disrupt aquatic ecosystems. Suspended particles absorb sunlight, increasing water temperature and subsequently decreasing dissolved oxygen levels, as warm water holds less oxygen than cold water. Additionally, high turbidity can impede photosynthesis by limiting light penetration (Alharbi et al., 2018), further reducing oxygen availability and potentially leading to the death of aquatic organisms.

Therefore, it is crucial to control turbidity and suspended solids in water to maintain water quality and protect aquatic life. According to the Malaysian National Water Quality Standards, the recommended turbidity level for drinking water should be below 1.0 NTU, and the total suspended solids (TSS) concentration should generally not exceed 300 ppm. Coagulation and flocculation are key physicochemical processes used in water and wastewater treatment to remove suspended solids, particularly fine particles that remain in a colloidal form and carry negative surface charges (Maćczak et al., 2022). These charges hinder natural aggregation, making it difficult for the particles to settle by gravity. The addition of coagulants facilitates the neutralization of these charges, enabling particles to aggregate into larger flocs that can subsequently settle during sedimentation or be removed via filtration (Al-Risheq et al., 2021; Mohd-Salleh et al., 2019; El-Taweel et al., 2023).

Two main categories of coagulants commonly used in the industry are inorganic metal salts and synthetic polymer-based coagulants. Inorganic coagulants, such as aluminium sulfate, ferric sulfate, and ferric chloride, are widely applied due to their high efficiency and low cost (Kumar Karnena & Saritha, 2022). On the other hand, synthetic organic polymers such as polyacrylamide derivatives and polyethyleneimine are typically high molecular weight polyelectrolytes that are effective in destabilizing colloidal particles through charge bridging and adsorption mechanisms (Koshani et al., 2020).

Despite their effectiveness, both inorganic and synthetic coagulants raise environmental and health concerns. Studies have suggested potential links between aluminum-based coagulants and neurodegenerative diseases such as Alzheimer's (Tomljenovic, 2011; Bongiovani et al., 2016) since the treated water contains chemical ionic residues. Furthermore, these coagulants can significantly alter water pH, often requiring the addition of pH-correcting agents such as lime or soda ash (Iwuozor et al., 2019), and tend to produce large volumes of metal-laden sludge, posing disposal challenges (Freitas et al., 2018; Souza et al., 2016).

Consequently, there has been increasing interest in the development of plant-based, biodegradable coagulants as more sustainable and environmentally friendly alternatives. Previous studies have demonstrated the effectiveness of natural coagulants derived from various botanical sources, such as *Moringa oleifera* seeds (Nhut et al., 2021), Nirmali seeds (Alenazi et al., 2020), and cactus extracts (Choudhary et al., 2018). Although natural coagulants may require higher dosages and are typically effective within a narrower pH range compared to synthetic polymers, their low toxicity, biodegradability, and lower sludge production offer significant advantages (Heiderscheidt et al., 2016).

Malaysia, endowed with rich biodiversity, presents abundant opportunities to explore local plant-based resources for water treatment applications. However, the potential of *Pandanus amaryllifolius* (commonly known as pandan leaf) and coconut husk as a natural coagulant remains underexplored. Pandan is widely available and traditionally used in culinary and preservation contexts due to its aromatic properties. Notably, it contains bioactive compounds such as tannins, flavonoids, and alkaloids, which are known to play important roles in particle destabilization and coagulation mechanisms. Meanwhile, coconut husk, an agricultural by-product commonly discarded as waste, is rich in lignocellulosic material and has been reported to contain functional groups such as hydroxyl and carboxyl. Its fibrous structure offers a large surface area, making it a potentially low-cost and sustainable coagulant material. Despite the abundance and accessibility of both pandan leaves and coconut husk in Malaysia, few studies have evaluated their effectiveness in turbidity removal.

This study, therefore, aims to explore the effectiveness of plant-based coagulants derived from pandan leaves and coconut husk in removing turbidity from river water under varying pH conditions and comparing their performance with conventional coagulants such as alum. In doing so, it seeks to contribute to the growing body of research on sustainable alternatives to conventional chemical coagulants, leveraging locally available natural resources for environmentally responsible water treatment practices.

MATERIALS AND METHODS

2.1. Materials

A water sample was collected from a nearby river in UMK Campus Jeli. Prior to treatment, the turbidity and pH were measured for each jar test run. Other water quality parameters were not determined, as the experiments were designed as preliminary screening tests focusing on turbidity removal and pH stability. Meanwhile, the pandan leaves and coconut husk were obtained from the local people in this area.

2.2. Coagulant preparation

Fresh pandan leaves (*P. amaryllifolius*) and coconut husk were collected and thoroughly washed with distilled water to remove surface impurities. The preparation of the coagulant solution was adapted from the method of Kumar Karnena & Saritha (2022), with slight modifications. The cleaned samples were air-dried under direct sunlight for approximately five days until a constant weight was achieved. Upon complete drying, the samples were ground into a fine powder using a mechanical grinder and subsequently sieved through a 0.25 μm mesh to ensure uniform particle size. Subsequently, 1 g of the coagulant powder was suspended in 100 mL of distilled water and mixed thoroughly. The mixture was filtered through Whatman filter paper, and the filtrate was used as the coagulant solution. All coagulant solutions were freshly prepared prior to each jar test experiment.

For comparison, alum coagulant solution was prepared using aluminium sulphate purchased from Merck. A stock solution of 1 g/L was prepared by dissolving 1 g of aluminium sulphate in 100 mL of distilled water. The stock solution was then diluted to obtain the desired concentrations for jar test experiments. All alum solutions and plant-based coagulants were prepared fresh before used.

2.3. Jar test experiment

2.3.1. Effects of dosage

The flocculator was used to carry out jar test experiment in sets. In this experiment, a 500 mL sample of river water from the UMK river was used to fill six beakers. Initial turbidity and pH were measured for each sample using a calibrated turbidimeter and pH meter. Then, predetermined doses of pandan leaf and coconut husk coagulant (10 to 60 mg/L) were accurately weighed using an analytical balance and added to each beaker. The coagulation process began with rapid mixing at 300 rpm for 2 minutes, followed by slow mixing at 30 rpm for 30 minutes to facilitate flocculation. After mixing, the samples were allowed to settle undisturbed for an additional 30 minutes.

After the settling period, the turbidity and pH of the supernatant were measured to assess the treatment performance. The turbidity removal efficiency (R_T%) was subsequently determined using Equation 1, where T_i and T_f denote the initial and final turbidity values, respectively.

$$R_T (\%) = [T_i - T_f] / T_i \times 100\% \qquad \text{Equation 1}$$

The optimal coagulant dose was identified based on the sample that exhibited the lowest turbidity removal percentage. The same procedure was subsequently repeated using alum as a reference coagulant. A comparative analysis was then conducted to evaluate the performance and optimal dosing of both metal-based and natural coagulants. These experiments were conducted as preliminary screening tests to evaluate the relative performance of pandan leaf and coconut husk coagulants across varying dosages and pH levels. Replicates were not performed at this stage; therefore, the results should be interpreted as indicative trends rather than statistically validated outcomes.

2.3.2. Effects of pH

The same jar test procedure described in Section 2.3.1 was employed to investigate the effect of pH variation on coagulant performance. The pH of the turbid river water was adjusted to pH 4, 7 and 12 using nitric acid (HNO_3) and sodium hydroxide (NaOH) solutions. Then, predetermined amounts of pandan leaf and coconut husk coagulant were added to each beaker containing water at a different pH level. The samples underwent the standard coagulation–flocculation process, followed by sedimentation. Final turbidity and pH values were measured and recorded. The same procedure was repeated using alum as a control coagulant. A comparative analysis was conducted to identify the most effective pH for turbidity removal for both coagulants.

2.4. Characterization of coagulants

2.4.1. Scanning electron microscopy (SEM)

A scanning electron microscope (SEM) is a type of characterization equipment that produces images of the surface of a sample by scanning with a focused electron beam. In this study, the surface morphology of coagulants from pandan leaves and coconut husk was analyzed using an SEM equipped with an energy dispersive X-ray spectroscope (SEM-EDX, model JSM-IT100). Observations were conducted at 600 magnifications and 20 kV) to evaluate the surface structure and the presence of elements in the coagulant samples.

2.4.3. Tannin content analysis

Tannin was qualitatively determined by adding 2 mL of ferric chloride ($FeCl_2$) solution to 1 mL of pandan leaf or coconut husk extract where the formation of a green coloration indicated the presence of tannins in the sample (Kumar Karnena & Saritha, 2022).

2.4.4. Flavonoid content analysis

Flavonoid content was determined following the method of Kumar Karnena & Saritha (2022). Briefly, 1 mL of sodium hydroxide (NaOH) solution was added to the pandan leaf and coconut husk extracts. The development of yellow coloration indicated the presence of flavonoids. To confirm this, a few drops of hydrochloric acid (HCl) were added, resulting in a reduction in color intensity, and thereby verifying the presence of flavonoid compounds.

RESULT AND DISCUSSION

3.1. Effect of pH and pandan dosage

The performance of *P. amaryllifolius* (pandan) extract as a natural coagulant was evaluated under varying initial pH conditions (acidic, neutral, and alkaline) and different dosages ranging from 10 to 60 mg/L. The turbidity removal efficiency and corresponding changes in pH before and after treatment are shown in Figures 1 to 3. At neutral pH, the turbidity removal efficiency peaked at 10 mg/L achieving 57% removal of turbidity (Figure 1). A marked decrease in efficiency was observed at 20 mg/L, suggesting potential overdosing and destabilization of colloidal particles. Similar overdosing effects, where excess coagulants cause re-stabilization of suspended solids due to charge reversal, have been reported for other plant-based coagulants (Yin, 2010). Beyond this point, efficiency fluctuated but did not surpass the performance at 10 mg/L. The pH remained relatively stable throughout the process, with final values ranging from 7.6 to 7.9, indicating that the pandan extract had minimal influence on the solution's pH in this condition.

Under acidic conditions (initial pH ~4), the highest turbidity removal of approximately 58% was achieved at a 40 mg/L dosage (Figure 2). However, the efficiency decreased sharply to 18% at 60 mg/L, also indicating a possible destabilization of particles due to excessive coagulant dosage. In contrast, pandan extract demonstrated superior coagulation efficiency under alkaline conditions (initial pH ~9), with turbidity removal reaching a maximum of 92% at 40 mg/L (Figure 3). Superior performance under alkaline conditions can be explained by the ionization and solubility of bioactive components in pandan leaves. Navera et al. (2013) identified tannins, flavonoids, sterols, triterpenes, alkaloids, saponins, and glycosides in pandan extract, with tannins and flavonoids being particularly relevant for coagulation. Nik Mohd Farid et al. (2020) reported that increasing pH enhances the cationic charge of tannins, improving their binding with negatively charged particles. Under alkaline conditions, these compounds become more soluble and ionized, promoting charge neutralization and adsorption bridging. This aligns with the sustained high removal observed at pH 9, confirming that alkaline conditions favor the coagulation activity of pandan extract. Furthermore, the final pH values remained above 9.8, showing only a slight reduction after treatment.

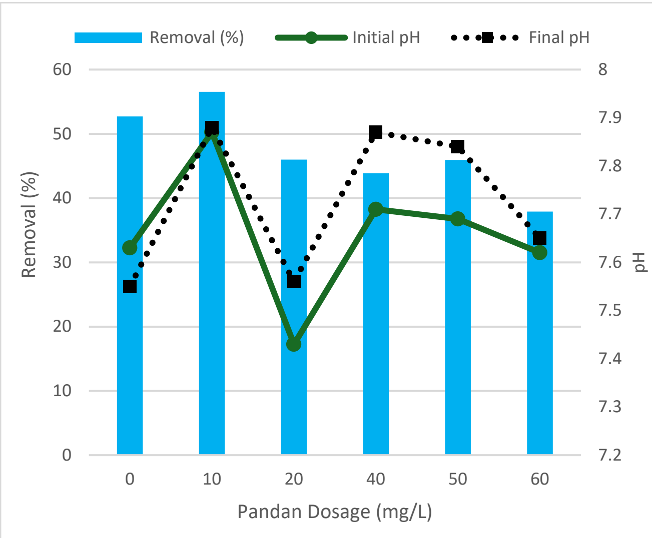

Figure 1: The removal of turbidity using pandan coagulant at pH 7.

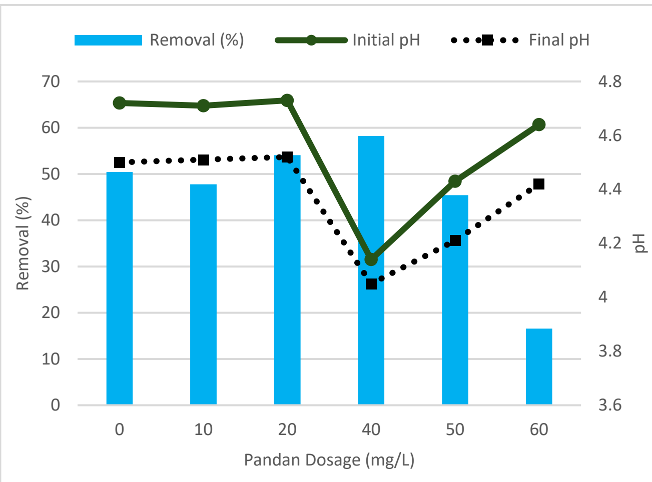

Figure 2: The removal of turbidity using pandan coagulant at pH 4.

It is important to note that pandan extract possesses a natural green coloration derived from chlorophyll and flavonoid compounds. While turbidity measurements primarily capture suspended solids, residual coloration at higher dosages may have contributed to the apparent turbidity, leading to potential underestimation of removal efficiency. Future work should include complementary colorimetric or spectrophotometric analysis to distinguish between particle removal and color interference.

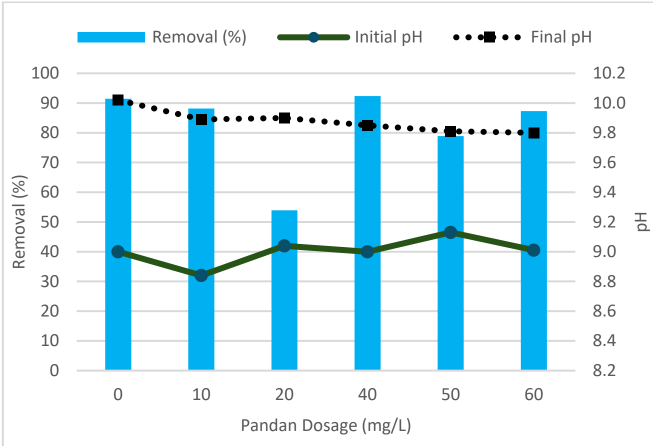

Figure 3: The removal of turbidity using pandan coagulant at pH 9.

3.2. Effect of pH and coconut husk dosage

The efficacy of coconut husk as a coagulant for turbidity removal was investigated over a range of initial pH values, with the results presented in Figures 4-6. A notable observation across all experimental conditions was the significant influence of initial solution pH on the overall removal efficiency. Figure 4, representing experiments conducted within an initial pH range of approximately ~4, illustrates the most promising turbidity removal performance. At a dosage of 10 mg/L, the highest removal efficiency of approximately 60% was achieved, suggesting an optimal interaction between the coconut husk and the suspended particles under these slightly acidic conditions. Under low pH, hydroxyl (–OH) and carboxyl (–COOH) groups in coconut husk become protonated, reducing their negative charge and thereby facilitating hydrogen bonding, cation bridging, and van der Waals interactions with negatively charged colloids (Varsani et al., 2024). The effectiveness of plant-based coagulants has been attributed to the presence of diverse bioactive compounds, such as tannins, flavonoids, saponins, and proteins, along with functional groups including hydroxyl, carboxyl, amino, phenolic, and sulfhydryl moieties. These components play key roles in destabilizing colloids, neutralizing surface charges, and promoting floc formation, thereby offering a sustainable mechanism for turbidity reduction compared to conventional chemical coagulants (Alnawajha, et al., 2022). However, beyond 10 mg/L, the removal efficiency declined, suggesting a possible overdosing effect or charge reversal that led to the re-stabilization of

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suspended particles. Such behavior has been described in previous studies, where excess natural coagulant disrupts the bridging mechanism or saturates available binding sites, thereby reducing efficiency (Yin, 2010).

At neutral initial pH range (~7) as depicted in Figure 5, the maximum turbidity removal was slightly lower, with ~56% removal at 10 mg/L. Similar to acidic conditions, efficiency decreased with increasing dosage. Increasing the dosage beyond this point led to a gradual decline in removal efficiency, reaching about 40% at 50 mg/L, before recovering to approximately 53% at 60 mg/L. In contrast, experiments conducted under alkaline conditions (Figure 6) demonstrated markedly lower removal efficiencies compared to acidic and neutral environments. The highest removal achieved was approximately 42% at 40 mg/L, in contrast to the lower optimal dosages observed under acidic and neutral pH. Across the tested dosages, removal percentages fluctuated between 30% and 40%. The reduced performance in this alkaline range can be attributed to changes in the surface charge of the coconut husk, where both the coconut husk and suspended particles are likely negatively charged, leading to electrostatic repulsion and poor floc formation. This charge similarity promotes electrostatic repulsion and hinders effective agglomeration. Previous studies have confirmed that hydroxyl groups in coconut husk (evidenced by FTIR peaks at ~3350 - 3320 cm^{-1}) remain active under alkaline pH (Kaur et al., 2025). However, their coagulation effectiveness may be reduced at high pH due to limited charge neutralization and weakened bridging interactions. Overall, these findings highlight that coconut husk performs best under acidic conditions, where protonation of functional groups reduces repulsion and promotes coagulation. At the same time, its performance is limited under alkaline conditions due to unfavorable electrostatic interactions at the surface.

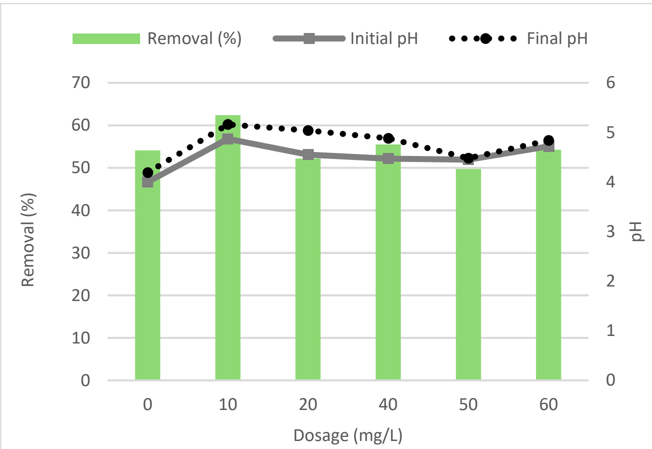

Figure 4: The removal of turbidity using coconut husk coagulant at pH 4.

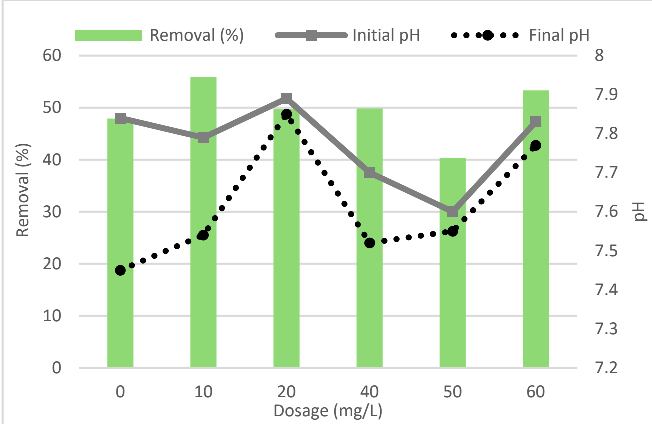

Figure 5: The removal of turbidity using coconut husk coagulant at pH 7.

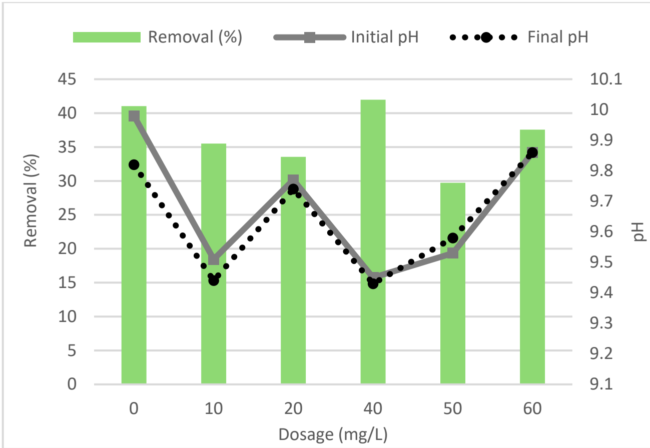

Figure 6: The removal of turbidity using coconut husk coagulant at pH 9.

3.3. Effect of pH and alum dosage

The efficacy of alum (aluminum sulfate) as a primary coagulant for turbidity removal was systematically evaluated across a range of dosages and initial pH values, as illustrated in Figures 7-9.. A consistent observation across all experiments was the strong dependence of removal efficiency on both alum dosage and the resulting pH environment.

Figure 7 depicts the turbidity removal performance when the initial pH was maintained at 4.1 to 4.5. At low alum dosages (10-20 mg/L), the removal efficiency was moderate, ranging from approximately 50% to 55%. However, a significant increase in removal efficiency was observed at 40 mg/L, achieving nearly 100% removal, which was sustained at 50 mg/L and 60 mg/L. This indicates a critical dosage threshold of 30-40 mg/L under these acidic conditions. Concurrently, the final pH showed a consistent decrease. This substantial pH reduction is characteristic of alum hydrolysis, where the release of H^{+} ions acidifies the solution. The excellent turbidity removal at higher dosages despite the decreasing pH suggests that the formation of positively charged aluminum hydroxide precipitates effectively neutralized the negatively charged colloidal particles, leading to superior coagulation.

In contrast, Figure 8 presents the results from experiments conducted with an initial pH around 7.0 to 7.4. Here, the optimal turbidity removal was achieved at lower alum dosages. At 10 mg/L and 20 mg/L, removal efficiencies reached approximately 92% and 95%, respectively, demonstrating exceptional performance. However, increasing the alum dosage beyond 40 mg/L led to a sharp decline in removal efficiency, dropping to around 45% and further to 35% at 60 mg/L. This re-stabilization of turbidity at higher dosages is a classic phenomenon in alum coagulation, often attributed to destabilization of particles due to charge reversal (Precious Sibiya et al., 2021). As alum dosage increases, the excess positively charged hydrolyzed species can re-charge the previously destabilized particles, leading to repulsive forces and poor flocculation. The final pH in this series decreased from approximately 7.1 at 0 mg/L to 5.5 at 60 mg/L, reflecting the acidifying effect of alum. The ideal performance at 10-20 mg/L corresponds to the formation of insoluble aluminum hydroxide flocs which effectively sweep-flocculate the turbidity.

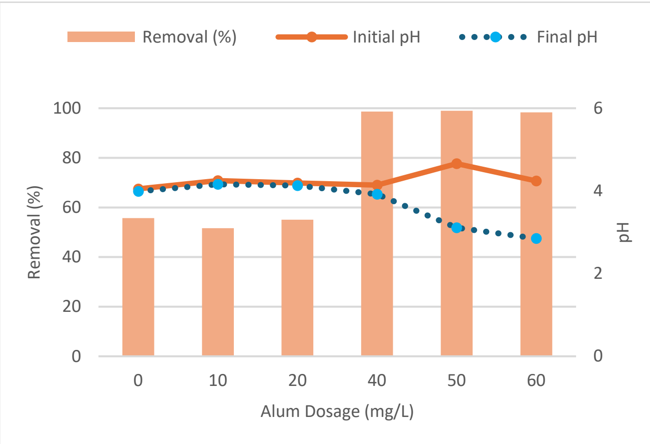

Figure 7: The removal of turbidity using alum at pH 4.

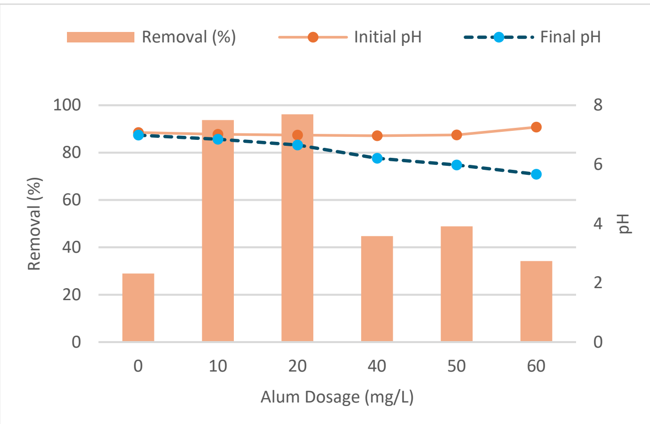

Figure 8: The removal of turbidity using alum at pH 7.

Lastly, Figure 9 illustrates the turbidity removal at an elevated initial pH of approximately 9.0 to 9.3. Under acidic conditions, the optimal removal efficiency was observed at higher alum dosages — 40 mg/L, 50 mg/L, and 60 mg/L — where nearly 100% turbidity removal was achieved. At lower dosages (0-20 mg/L), the removal efficiency was moderate, ranging from 55% to 58%. The final pH in this series decreased from 9 to below pH 7, demonstrating the strong acidifying effect of alum. The excellent performance at higher dosages in this alkaline range is likely due to the alum effectively overcoming the high initial alkalinity, bringing the solution pH into a more favorable range for the formation of charge-neutral or slightly positively charged aluminum hydroxide precipitates, facilitating efficient sweep flocculation.

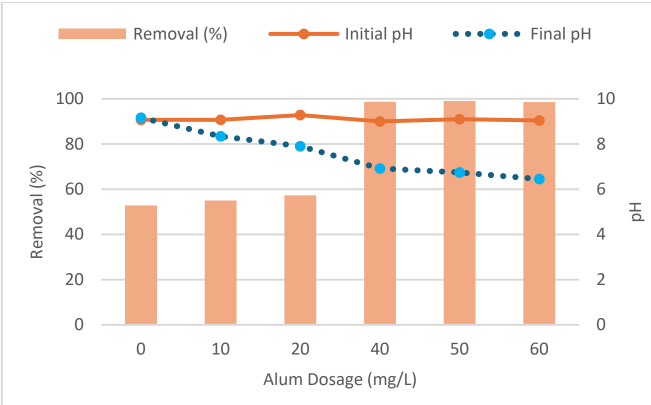

Figure 9: The removal of turbidity using alum at pH 9.

3.4. Comparison between alum and plant-based coagulant

Figure 10 presents a comparison of turbidity removal efficiency between different types of coagulants at varying pH levels. Among the tested coagulants, alum, a commonly used synthetic coagulant in wastewater treatment, demonstrated the highest turbidity removal efficiency, particularly under alkaline conditions.

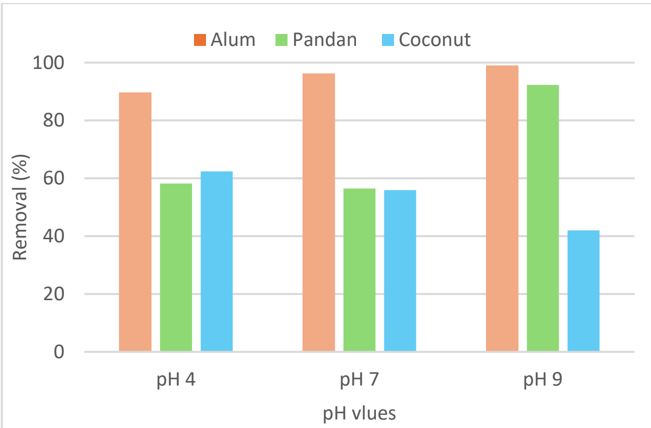

Figure 10: The comparison of turbidity removal using various coagulants at different pH medium.

Although alum demonstrated the highest turbidity removal efficiency, achieving >99% removal across both acidic and alkaline conditions, the performance of pandan and coconut husk coagulants was comparatively lower. Pandan extract achieved up to 90% turbidity reduction at alkaline pH (pH 9) with a dosage of 40 mg/L, while coconut husk reached approximately 60% removal under acidic conditions (pH 4) at a dosage of 10 mg/L. While these efficiencies do not surpass those of alum, their performance highlights an important advantage: unlike alum, pandan and coconut husk use did not significantly alter the final pH of treated water. This suggests that plant-based coagulants may provide a safer and more sustainable alternative, particularly in applications where chemical residues and post-treatment pH adjustment are concerned. Moreover, given their renewable, biodegradable nature and local availability, further optimization of dosage, extraction techniques, or blending with other natural coagulants could substantially improve their performance and make them competitive with conventional chemical coagulants.

3.5. SEM images

Figures 11 and 12 show the morphology of coconut and pandan at 600 image magnifications respectively Based on the figures, various shapes and sizes with a fiber-like network were observed on the surfaces of the pandan particles. Regarding the coconut morphology, a pore-and-hole structure is observed on the coarse particles. Besides, it shows a rough surface structure.

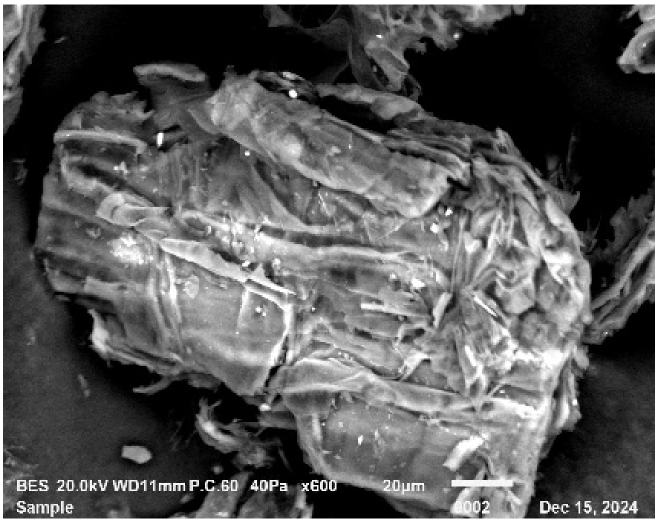

Figure 11: The morphology image of coconut at 600x magnification.

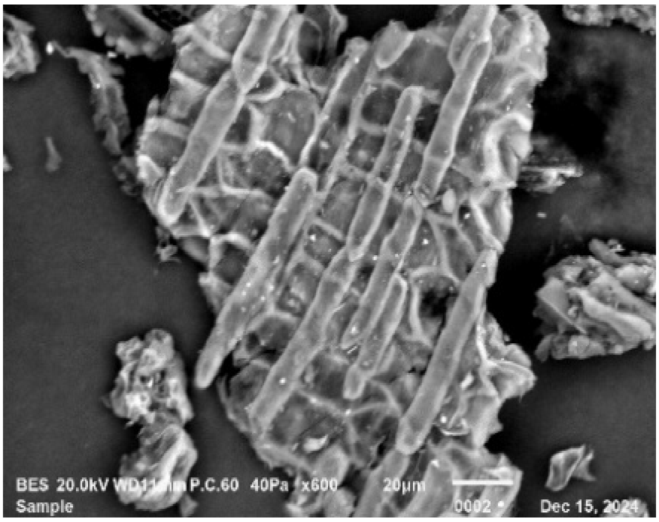

Figure 12: The morphology image of pandan at 600x magnification.

3.6. Tannin and flavonoids

Numerous studies have demonstrated that tannin-based coagulants are effective in adsorbing turbidity, color, and chemical oxygen demand (COD) from water sources (Leiviskä & Santos, 2023). In light of this, a qualitative analysis for tannin content was conducted on pandan and coconut coagulant samples, with the results presented in Figure 13.

As shown in Figure 13 ai), the coconut husk coagulant exhibited a positive reaction for tannins. In the test, coconut husk powder was dissolved in water and divided into two test tubes for comparison: the test tube labeled before served as the control, while the one labeled after was the test sample. Both tubes were treated with 5% ferric chloride ($FeCl_3$). The appearance of a dark green coloration in test tube sample (labeled after) indicates the presence of tannins in the coconut sample. This observation is consistent with the findings of Sirisangsawang & Phetyim (2023), who also confirmed the presence of tannins in coconut coir extracts using both water and ethanol as solvents. Their study reported that ethanol-extracted samples exhibited a more intense blackish-green coloration, further supporting the sensitivity of this colorimetric test to tannin content.

In contrast, the pandan coagulant sample (Figure 13aii) produced a darker yellowish-brown coloration upon reaction with ferric chloride. Although this color shift did not match the deep green typically associated with tannins, previous work by Nguyen et al. (2021) confirmed the presence of tannins in pandan leaf extracts. Their study further demonstrated that the pandan-based coagulant achieved up to 90% turbidity removal under alkaline conditions (pH 9), supporting its potential as an effective natural coagulant.

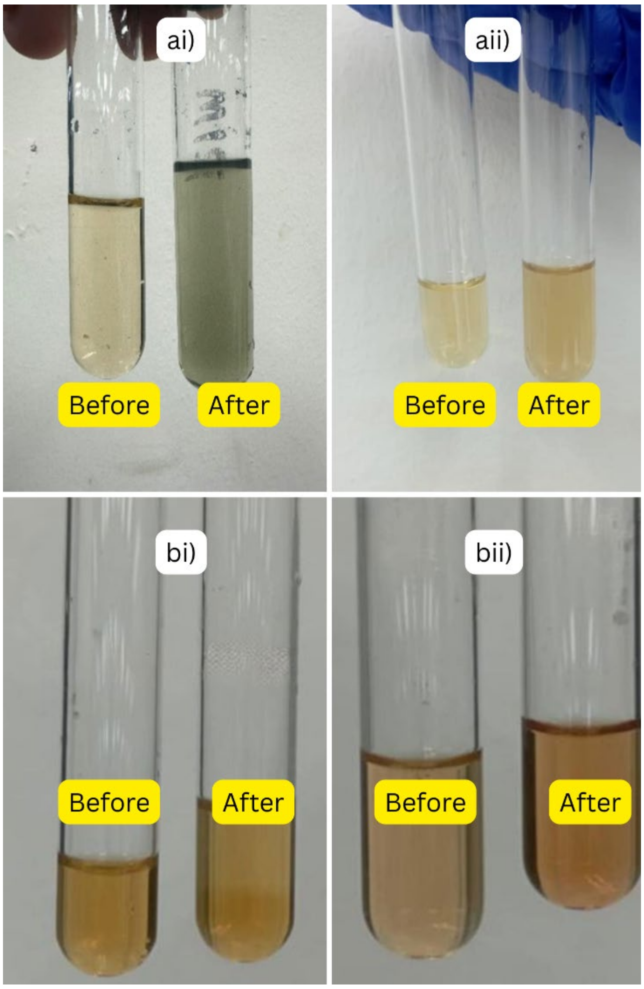

Figure 13: Colour change before and after a) tannin and b) flavonoid test on i) coconut husk and ii) pandan leaves.

Meanwhile, the presence of flavonoids in pandan and coconut coagulant samples was evaluated using a qualitative chemical test, with the outcomes illustrated in Figure 13 bi) and bii). According to Fransina et al. (2019), flavonoid-containing samples will exhibit a colour change to green, brown, or yellow upon addition of a sodium hydroxide (NaOH) solution. However, this colour typically fades or becomes diluted when hydrochloric acid (HCl) is subsequently added, indicating the reaction's reversibility.

In this analysis, powdered samples of pandan and coconut husk were dissolved in water and distributed into two test tubes labeled as before served as the control, while the one labeled after was the test sample. Both tubes were treated with NaOH. As shown in the Figure 13 b), both coconut (bi) and pandan (bii) coagulant solutions displayed a distinct brownish-yellow color upon NaOH addition, which later faded upon the introduction of HCl, suggesting the presence of flavonoid compounds in both samples. These findings are supported by Nguyen et al. (2021), who reported that pandan contains several phytochemical constituents, including polyphenols, alkaloids, saponins, tannins, and flavonoids. Similarly, Wahab et al. (2023) confirmed the presence of flavonoids in coconut fiber, further validating the outcome of this experiment.

This study confirmed the presence of tannins and flavonoids in pandan leaf and coconut husk extracts using qualitative colorimetric tests. While effective for preliminary screening, such methods do not provide quantitative information. Future studies should incorporate spectrophotometric or chromatographic approaches to determine the actual concentrations of these bioactive compounds. This would enable a clearer understanding of the relationship between phytochemical content and coagulation performance, potentially enhancing the optimization of plant-based coagulants.

4. CONCLUSION

This study explored the potential of plant-based coagulants specifically pandan and coconut in reducing water turbidity. The findings demonstrated that both natural coagulants possess promising coagulation properties, although their performance varies depending on pH conditions. Pandan coagulant achieved the highest turbidity removal of 90% at pH 9 with a dosage of 40 mg/L, indicating its effectiveness in alkaline conditions. In contrast, coconut coagulant performed best in acidic conditions (pH 4) with a 60% turbidity removal at a lower dosage of 10 mg/L. Despite these promising outcomes, it is important to note that the turbidity removal efficiencies of pandan and coconut husk were lower than that of alum, which consistently achieved up to 99% removal across a broad pH range (4–9). Nevertheless, the use of pandan and coconut husk offers distinct advantages. Unlike alum, which significantly reduced the final pH of treated water, both plant-based coagulants caused minimal changes to pH, reflecting their environmentally friendly and stable characteristics. Moreover, their renewable, biodegradable nature and local availability strengthen their potential as sustainable alternatives, especially in low-cost or rural water treatment applications. Scanning electron microscopy (SEM) analysis of both pandan leaf and coconut husk coagulants revealed fiber surface morphologies characterized by rod-like structures and the presence of fine pores, indicating a high potential for particle adsorption. Phytochemical screening further confirmed the presence of tannins and flavonoids in both samples. These bioactive compounds are known to contribute to coagulation efficiency and are key indicators of effective plant-based coagulants. To enhance the effectiveness of plant-based coagulants in future studies, several improvements are suggested. Firstly, optimization of the extraction process using advanced techniques, such as solvent extraction or ultrasonic-assisted extraction, is recommended to increase the yield and concentration of active compounds, such as tannins and flavonoids, which are responsible for coagulation performance. Secondly, future studies should use water or wastewater samples with higher turbidity to assess the applicability of these coagulants under practical and variable environmental conditions.

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