MULTIDISCIPLINARY APPLIED RESEARCH AND INNOVATION
e-ISSN: 2773-4773

MARI

Vol. 6 No. 3 (2025) 78-89
https://publisher.uthm.edu.my/periodicals/index.php/mari

Study of Effectiveness Longan Seed as Natural Coagulants for Textile Wastewater Treatment

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DOI: https://doi.org/10.30880/mari.2025.06.03.011

Article Info

Received: 1 March 2025
Accepted: 1 May 2025
Available online: 30 June 2025

Keywords

Longan seeds, natural coagulant, textile wastewater, JAR test, XRD and SEM, sodium chloride

Abstract

This research investigates the coagulation efficacy of longan seed powder as a natural coagulant in treating textile wastewater that contains dangerous pollutants. The experiments were conducted at the laboratory level after analysing the properties and morphology of longan seed powder with the help of X-ray diffraction (XRD) and scanning electron microscopy (SEM). The potential for dry longan seed powder to act as a coagulant is investigated to treat textile wastewater within a range of concentrations of NaCl solution. The removal efficiency of the coagulation process is also tested for different masses of longan seed powder. The raw material of longan seeds was ground into a powder and mixed with sodium chloride (NaCl) and distilled water to produce NaCl concentrations. The initial data taken were turbidity, pH, COD, and colour to determine the effectiveness of longan seeds as natural coagulants in textile wastewater. X-ray diffraction (XRD) was used to characterize the crystalline structure of longan seeds while scanning electron microscopy (SEM) was employed to measure the size and shape of the seeds. A proper characterization of the longan seeds was applied using the X-ray diffraction (XRD) technique, which showed the crystalline patterns of polyphenolic compounds and minerals. This study shows that among four different concentration solvents, 0.5 mol NaCl is the most optimum condition for longan seed results in textile wastewater. Moreover, the finding of this study is that longan seeds can treat textile wastewater by reducing the dosage required in the process of treating textile wastewater until an optimal result is achieved.In conclusion, it is substantiated by the present study that a natural coagulant prepared from longan seeds can be effective for the treatment of textile wastewater. In addition, it benefits by promoting sustainable waste management practices, offering a cost-effective alternative for wastewater treatment, and reducing environmental contamination risks.

1. Introduction

The purpose of this experiment was to determine the effectiveness of longan seeds as coagulants in cleaning effluent from the textile industry. The textile industry is a major source of environmental pollution, producing large amounts of wastewater contaminated with various pollutants such as heavy metals, dyes, and other toxins [1]. These contaminants pose serious environmental and health risks, making it imperative to address the effects of textile waste on the environment for sustainable development and environmental preservation. Traditional textile wastewater treatment processes often rely on synthetic chemicals, which may be hazardous to human health and the environment [2]. Consequently, research into natural and eco-friendly wastewater treatment methods is gaining momentum. Among these methods, the coagulation-flocculation process stands out as one of the most popular and effective techniques for treating industrial wastewater.

Textile wastewater is a complex mixture of chemicals, dyes, and particles that poses a significant environmental challenge due to its untreated nature. The contaminants in textile wastewater include organic compounds, dyes, heavy metals, and suspended solids, all of which can have detrimental effects on aquatic ecosystems and human health. The wastewater treatment industry needs to focus on developing technologies that enable efficient treatment of organic wastewater with high pollutant concentrations while allowing for resource recovery. Current textile wastewater treatment technologies often combine biological and physio-chemical techniques to remove pollutants and toxic chemicals [3]. Among these techniques, the use of coagulants—whether chemical or natural—plays a crucial role in inducing coagulation and separating fine particles from the wastewater.

Natural coagulants, such as moringa seeds and longan seeds, are being explored as eco-friendly alternatives to chemical coagulants due to their sustainability, biodegradability, and cost-effectiveness. These natural coagulants offer several advantages, including reduced environmental impact and availability from renewable resources. However, more research is needed to fully understand their effectiveness and the mechanisms by which they work. This study aims to fill this gap by investigating the potential of longan seeds as a natural coagulant for textile wastewater treatment. The study will characterize the properties and morphology of longan seed powder using X-ray diffraction (XRD) and scanning electron microscopy (SEM).

Previous studies have shown that natural coagulants can be effective in wastewater treatment. For example, moringa seeds have been widely studied and demonstrated to have significant coagulating properties[4] However, there is limited research on the use of longan seeds for this purpose. This study aims to build on previous research by exploring the coagulating potential of longan seeds and comparing their effectiveness to other natural and chemical coagulants. By doing so, the study seeks to contribute to the development of sustainable and eco-friendly wastewater treatment methods.

Current treatment methods for textile wastewater involve a combination of biological and chemical processes [5]. Biological treatments often include the use of microorganisms to degrade organic pollutants, while chemical treatments involve the use of coagulants and flocculants to remove suspended solids and other contaminants [6]. However, these methods have limitations, including high operational costs, potential health hazards from chemical coagulants, and the generation of secondary pollution. This study aims to address these limitations by exploring the use of longan seeds as a natural coagulant, which could offer a safer and more sustainable alternative.

The gap in the current research lies in the limited understanding of the effectiveness of longan seeds as a natural coagulant for textile wastewater treatment. While previous studies have explored the use of various natural coagulants, there is a need for more comprehensive research on the properties and mechanisms of longan seeds. This study aims to fill this gap by conducting a detailed investigation into the coagulating properties of longan seeds, including their ability to induce coagulation in different concentrations of Sodium Chloride (NaCl) solution and the effectiveness of varying masses of longan seeds as a coagulant.

In conclusion, this study aims to investigate the potential of longan seeds as a natural coagulant for textile wastewater treatment. The objectives include determining the characteristics and morphology of longan seed powder using XRD and SEM, and evaluating the effectiveness of different concentrations of NaCl solution and varying masses of longan seeds in treating textile wastewater. By addressing the gap in current research and exploring the potential of longan seeds, this study seeks to contribute to the development of sustainable and eco-friendly wastewater treatment methods that can mitigate the environmental impact of the textile industry.

2. Materials and Methods

The project approach illustrated in Fig. 1 entails carrying out research to achieve the project's main goals, which include determining whether dried longan seeds perform well as coagulants in the context of wastewater treatment.

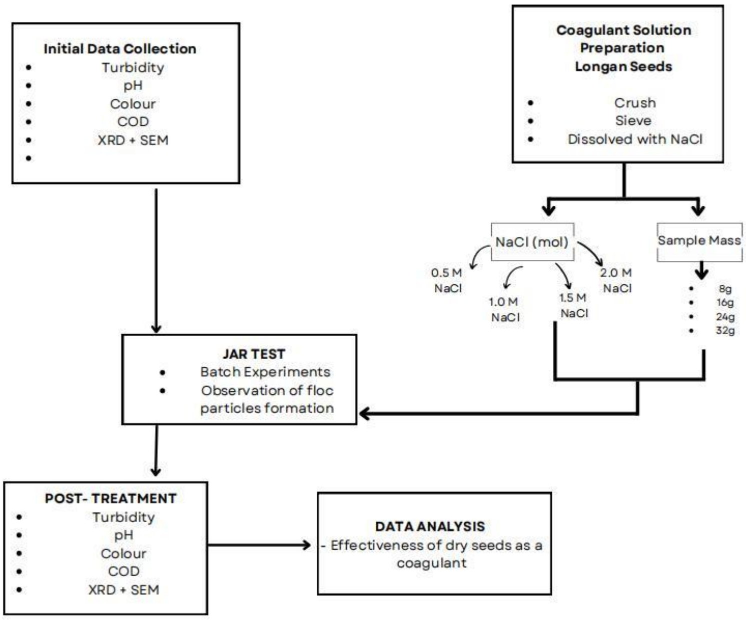


Fig. 1 *Study Flowchart*

The three main phases of the study process are pre-treatment, wastewater treatment process simulation, and post-treatment. The first stage involves the collection of initial data from the wastewater samples, namely turbidity, COD, color, and pH, as well as X-ray diffraction (XRD) and scanning electron microscopy (SEM). Also in the first stage is the synthesis of a coagulant solution using dry longan seeds. Longan seeds that have been dried and then crushed into powder are the main components used to make the coagulant solution. Different amounts of NaCI solution were used to dissolve powdered longan seeds. In the second stage, the jar test method was used to simulate the wastewater treatment process and analyse the ability of dried longan seeds to dissolve in different concentrations of sodium chloride (NaCl) solution as a coagulant. The post-treatment data was carried out after treatment, which is COD, turbidity, color, and pH. The data analysis was carried out according to the effectiveness of dry longan seeds in different concentrations and in different masses.

2.1 X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM)

X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) are used to analyze longan seed powder's crystallographic structure and phase composition. XRD generates a diffraction pattern, while SEM examines surface morphology and microstructure. The powdered sample is coated with a thin conductive layer, providing detailed visualization of microstructural features and irregularities. The use of XRD in this research is used to identify crystal structure and atomic spacing A crystalline sample and monochromatic X-rays interfere constructively to produce X-ray diffraction [2].

2.2 Chemical Oxygen Demand (COD) Reduction Calculation

Chemical oxygen demand (COD) is an important parameter to assess the level of organic pollutants in wastewater, especially industrial effluents. This study collects COD data by adding 2.0 ml of wastewater samples that have been experimented with jar tests in different concentrations to the COD reactor for 2 hours at 150 °C, then calculating the COD removal percentage using the Equation 1 formula to determine the effectiveness of the longan seed in reducing the COD of the water.

$$\%\ \text{COD removal} = \frac{initial\ COD - final\ COD}{initial\ COD} \times 100 \quad (1)$$

2.3 Turbidity Reduction Calculation

Turbidity is created by suspended particles such as silt and clay, which have an impact on water quality and treatment effectiveness. Turbidity readings taken both before and after the Jar Test are used in this study to determine the effectiveness of turbidity reduction. Water samples are put in cuvettes and indexed to the lowest reading to get the NTU value. The percentage of turbidity removed and the effective treatment dose are determined by the recorded results. Eq.2 was utilised to evaluate the effectiveness of Longan seed in reducing the turbidity of the water.

$$\% \text{ Turbidity removal} = \frac{initial\ turbidity - final\ turbidity}{initial\ turbidity} \times 100 \quad (2)$$

2.4 Color Reduction Calculation

Color removal evaluates the efficiency of freezing in removing color-causing substances from water. It involves monitoring color changes during and after freezing to ensure the effectiveness of longan seeds as a coagulant for wastewater treatment. This study used a colorimeter cuvette filled with wastewater samples to measure the color intensity, record the readings, and calculate the effectiveness value for longan seeds using Eq.3.

$$\% \text{ Color removal} = \frac{initial\ color\ - final\ color}{initial\ color} \times 100 \quad (3)$$

3. Result and Discussion

The discussion intended to examine the XRD and SEM properties of the longan seed powder after the seeds were prepared in a powdered format. This also investigated the efficacy of different concentrations of Sodium Chloride (NaCl) solution on the coagulant ability of longan seed and compared the ability of varied masses of longan seed to enhance the quality standard of textile wastewater.

3.1 Characteristic Analysis

The physicochemical analysis is used as a multi-faced approach that delves into the intricate details of the physical and structural properties of longan seeds powder, unravelling crucial insights that contribute to the understanding of this natural material. The use of X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) in this study provides the characteristics of longan seed powder about its morphology and structures.

3.1.1 X-ray Diffraction (XRD)

The graph gathered in Fig. 2 entails information about the XRD (X-ray diffraction) pattern that can be analyzed to determine the crystalline structure, phase composition, and crystallite size of the material. The peak was determined through the analysis of peak positions and their corresponding intensity and width values of the XRD graph. The X-ray diffraction (XRD) analysis of longan seed powder primarily reveals peaks corresponding to sodium silicate (Na_2SiO_3) and silicon dioxide (SiO_2), indicating the presence of these compounds as significant crystalline phases. The distinct peaks of sodium silicate suggest that the synthesis or presence of this compound may have occurred due to the inherent composition of longan seeds, which could contain naturally occurring silicate compounds, or because of processing conditions that lead to silicate formation. Sodium silicate is often synthesized from silica sources, and its presence aligns with observations in other plant-based studies where silicates form under certain treatment conditions [7].

Silicon dioxide, observed as another primary phase in the XRD analysis, is a stable form of silica commonly found in plant materials, especially in ash derived from biomass. The crystalline peaks associated with silicon dioxide confirm its structural stability, which could contribute to its utility in diverse applications, such as reinforcing materials or as an adsorbent. Silica from plant-based sources has gained attention for its environmental and economic benefits as an alternative to synthetic silica. Studies have shown that plant-derived silica maintains a stable structure after thermal treatments, enhancing its functionality in industrial applications [8].

The XRD pattern of the longan seed also highlights a broad range of minor peaks, which could indicate the presence of other mineral phases or amorphous structures that may be less defined in terms of crystallinity. This mixed phase structure is common in plant materials where various minerals coexist, contributing to the complexity of the diffraction pattern. Similar studies on biomass like rice husk and sugarcane bagasse ash demonstrate that such mixed phases, including amorphous silica, can emerge after pyrolysis or similar treatments, adding versatility to their applications in environmental and material science [8].

In summary, the XRD data for the longan seed confirms the presence of crystalline sodium silicate and silicon dioxide, with additional amorphous or minor crystalline phases that add complexity to its mineral composition. This analysis is consistent with findings in recent studies on biomass-derived silica and silicates, underscoring their potential for sustainable materials development. The presence of these compounds within the longan seed suggests opportunities for its use as an eco-friendly source of silica and silicate compounds, aligning with current trends in green chemistry and materials engineering [7;9].

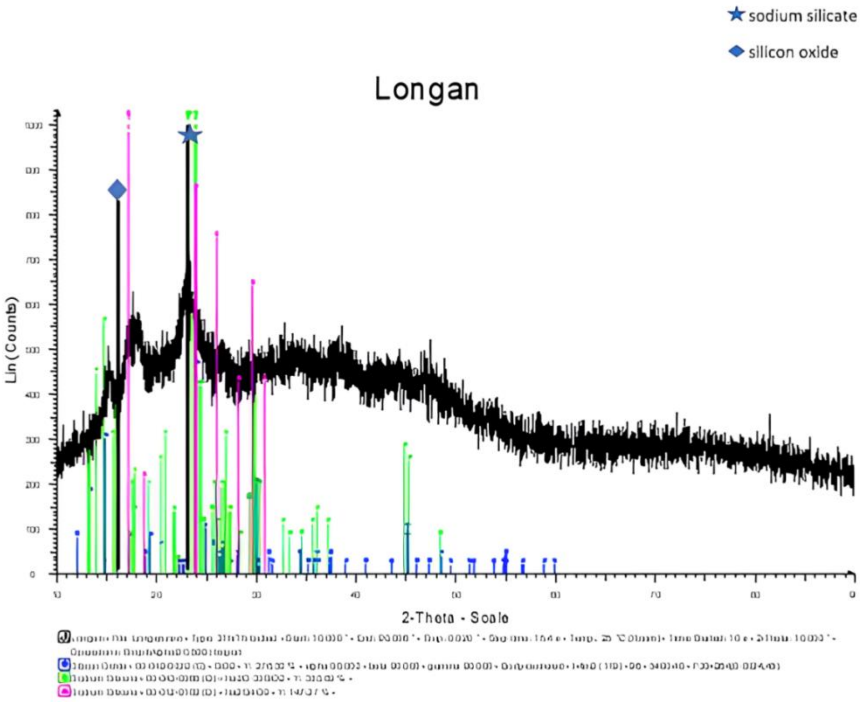
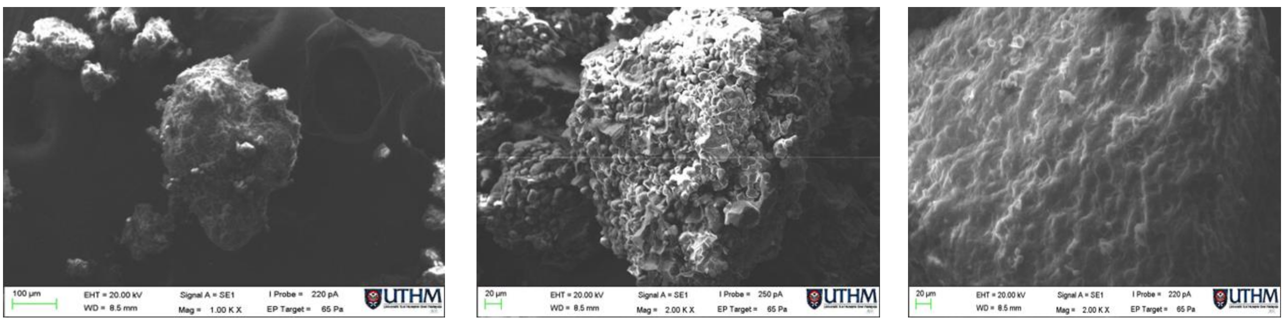


Fig.2 *X-ray Diffraction (XRD) of Longan Seeds*

3.1.2 Scanning Electron Microscopy (SEM)

The morphology of the longan seeds was characterized using Scanning Electron Microscopy (SEM), with image shown in Figure 3. Through this method, topological pictures are created by utilising the interaction between the electrons and the material. The electron microscope, which has a greater magnification than a light microscope, has made it possible for researchers to view the material at a level of detail that is beyond the reach of the human eye [10].



(a) **(b)** **(c)**

Fig.3 *Scanning Electron Microscopy (SEM) Image of Longan Seed Surface (a) 100x Magnification; (b) 20x Magnification; (c) 20x Magnification*

Following the findings in Fig. 3, the longan seeds showed an oval and polygonal shape with sharp edges and a wide variety of cylindrical holes appeared on the surface of longan seeds which were connected by dense compact structures. Therefore, it believes that devolatilization and volatile release from the longan seeds are the factors that lead to the creation of the pore formation [11].

Furthermore, the porous structures during the carbonation process are the main factors that facilitate carbon capture. Longan seeds had many minerals, but it was a short life of seed, and its release of volatile was a long distance. The composition of the longan seeds such as protein, lipid and carbohydrate can be indicated by sharp, distinct peaks corresponding to the crystalline structure of those minerals and it shows that among the minerals, magnesium and iron contents were higher in the seed [12].

3.2 Efficacy of Longan Seed Coagulant in Different Concentrations

3.2.1 Turbidity Removal

Given the data recorded in Fig. 4 it can be observed that all doses illustrated a positive trend in turbidity removal as dose increases. The 0.5M concentration starts at 10 ml with about 41% removal and incrementally reaches 50% at 25 ml. On the other hand, the 1M concentration begins at roughly 43% and goes up to around 49% at 25 mL while the 1.5M concentration begins from about 45% and rises to approximately 48% at 25 ml. Furthermore, the type and concentration of sugars like fructose, sucrose, and glucose present in longan seeds [13] slightly diminish the efficacy of turbidity removal in water treatment. It is the same way that for 2M concentrations, which start off from almost 45% and rise to almost 47% at 25 mL. However there are no significant variations among them since their turbidity removal efficiencies are nearly equal. However, when compared on a dosage basis, then is less than ideal separation between them both. Therefore, a lower efficiency in removing turbidity is shown by 2M dosage than 0.5M dosage which removes it effectively.

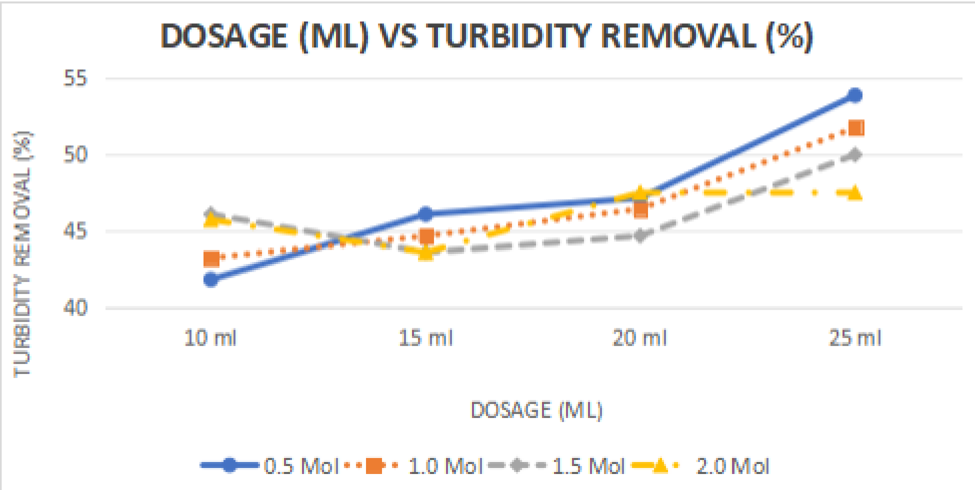


Fig.4 *Dosage (mL) vs turbidity Removal (%)*

3.2.2 COD Removal

According to Fig. 5, a dosage of 1M is the most effective in the removal of COD because it maintains a stable efficiency between 20% and 30%, while those of 0.5M and 2.0M are largely inept resulting in negative removal rates; and for the 1.5M dose, it gives variable results generally offering poor performance.

The increase in COD is due to the presence of a lot of organic matter in longan seeds. This type of organic material, primarily composed of complex polysaccharides and phenolic compounds, cannot be broken down efficiently by microorganisms involved in the biological decomposition process [14]. Consequently, these complex organic compounds remain in the wastewater, thereby preventing the reduction of COD values. The other inorganic substances like chloride lead to false high-test values for CODs. Additionally, there will be the formation of intermediate products that are stable during the degradation of complex compounds even though this process also occurs which as well induces more complexity into the situation. Moreover, longan seeds consist of a mixture of sugars, proteins, fats, and other organic materials which alter the reactivity towards oxidizing agents used for the determination of COD.

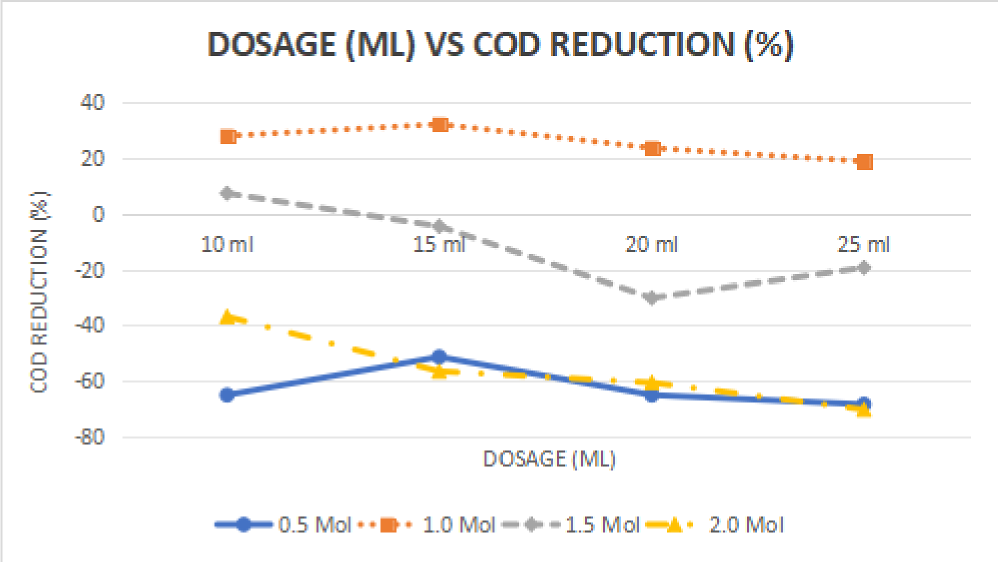


Fig.5 *Dosage (mL) vs COD Removal (%)*

3.2.3 Color Removal

The results of color reduction percentage at 0.5M shown in Fig. 6 indicate that as the dosage increases, the color removal efficiency varies depending on the concentration of the solution. From this, it can be deduced that the color removal efficiency decreases with an increase in dosage at lower concentrations, while at higher concentrations, the efficiency is indifferent to change with dosage. At a concentration of 0.5M, increasing the dosage from 10 mL to 25 mL shows minimal impact on color removal, with the percentage remaining roughly constant at around -25%. This finding aligns with the observation of longan seeds, due to their composition rich in refractory compounds like tannins and lignin, exhibit minimal changes in color even with increasing dosage [15].

Similarly, at higher concentrations such as 1.0 mol, 1.5 mol, and 2.0 mol, the results show a decreasing trend in color removal efficiency as dosage increases. This decreasing trend corresponds to the presence of natural pigments in longan seeds, which can mask or obscure the expected color changes despite variations in dosage [16]. Moreover, the high antioxidant content in longan seeds [17] acts as a stabilizing factor, preventing the oxidation reactions for color changes. This aligns with the results showing minimal color variation despite changes in dosage, particularly evident at higher concentrations where the steep decline in color removal efficiency occurs. Overall, the results underscore dosage, concentration, and the properties of longan seeds in determining color removal efficiency. Overall, physical and biochemical changes in longan seeds during development and ripening of the fruit play a key role in determining its effectiveness as a natural coagulant. That would be great potential in reducing the color and improving the quality of textile wastewater through a more environmentally friendly treatment process [15].

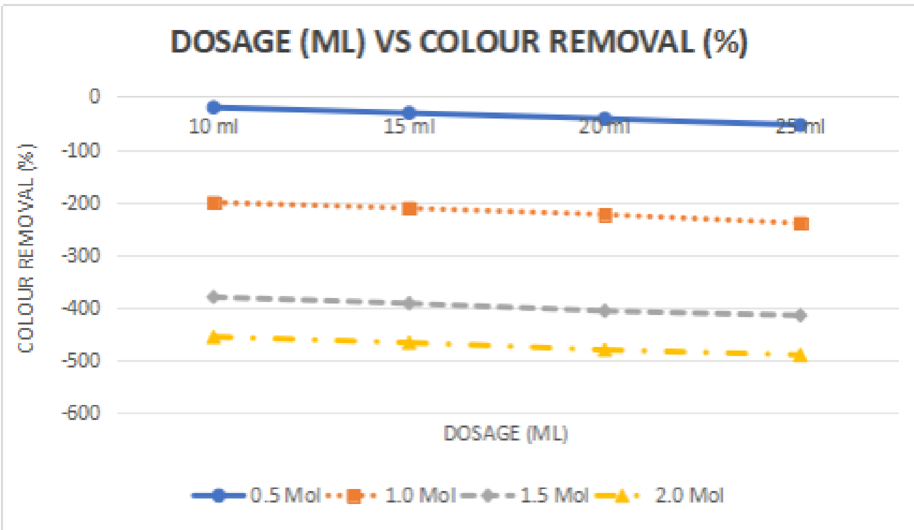


Fig. 6 *Dosage (mL) vs Color Removal (%)*

3.2.4 pH

The graph in Fig. 7 shows that when the dose increases from 10 ml to 25 ml, the pH decreases slightly from about 8.3 to 8.2 for 0.5 M. It's more noticeable than about 8.25 to 8.1 for 1.0 M, which is a decrease than approximately 8.1 to about 7.9 for 1.5 but more visible than 8.25 to 8.1 for 1.0 M. For a 2.0M concentration of NaCl, the reduction range was from roughly 8.0 to 7.8.

The tendency for the pH to decrease at all concentrations when the dose of the added solution is increased is due to the NaCl content. Since pH measures the concentration of hydrogen (H+) ions, adding a solution can increase the H+ ion concentration, thereby lowering the pH. A higher density of the solution means more H+ ions, leading to a more significant impact on pH when added to textile wastewater, thus resulting in a more pronounced effect with larger doses [18].

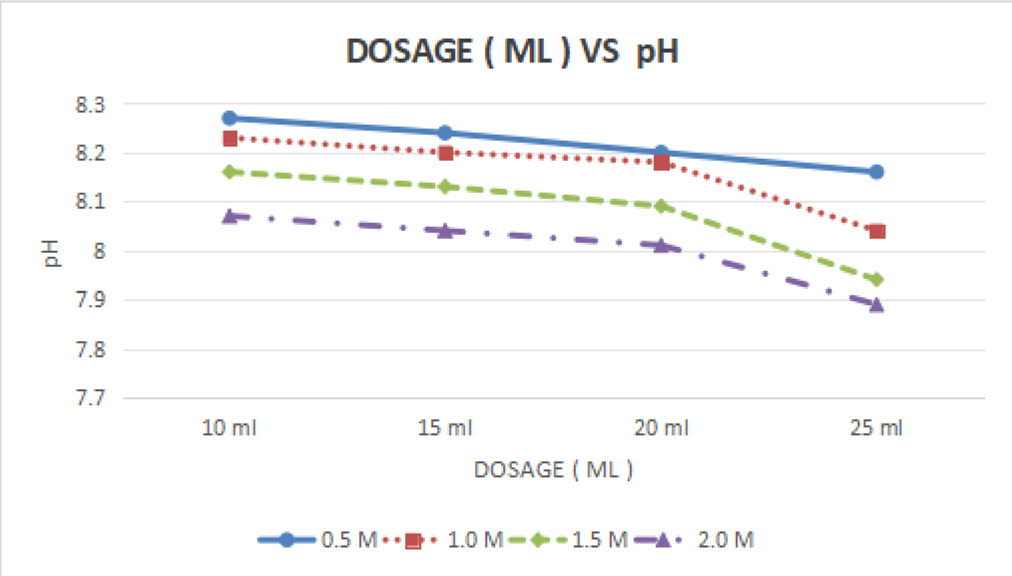


Fig.7 *Dosage (mL) vs pH*

3.3 Efficacy of Longan Seed Coagulant in Different Mass

3.3.1 Turbidity Removal

Longan seed mass is an important parameter in determining coagulant performance in wastewater treatment flocculation. Fig. 8 illustrates a graph of the percentage removal of turbidity with a total dose for different masses. The results showed that in the 8g and 16g masses, there was an increase in the turbidity flow as the coagulant dose increased but the opposite was true for the 24g and 32g masses. At a mass of 8g, there was a sharp increase in turbidity flow after a coagulant dose of 15 mL.

At a mass of 8g, the material's adsorption sites become saturated, or optimal coagulation is achieved. Beyond this level, additional mass produces diminishing returns. Adding more material beyond the saturation point can cause particle crowding, where excess material particles can interfere with each other, reducing turbidity removal efficiency. The 8 grams of 25 ml point may represent the optimum dose at which the highest efficiency is achieved. Also, the percentage of turbidity removal may not increase significantly and may even decrease if the system is destabilized by excess material [19].

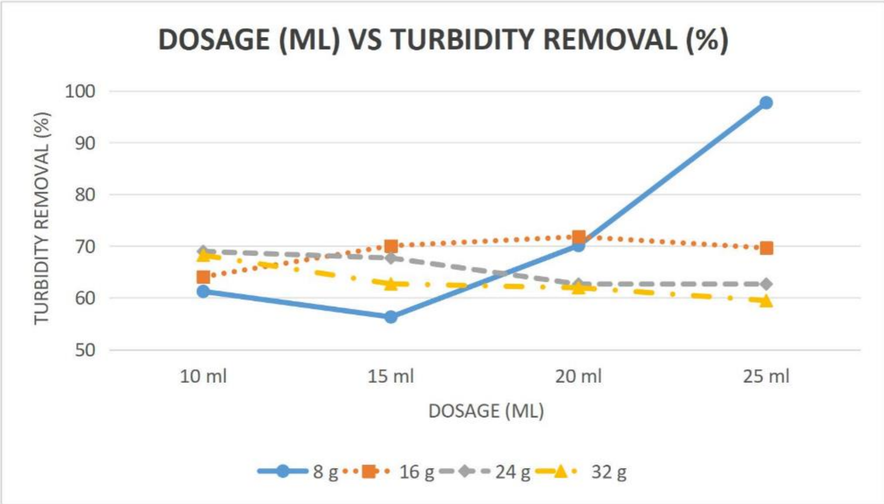


Fig. 8 *Dosage (mL) vs Turbidity Removal (%)*

3.3.2 COD Removal

A decreasing trend has been obtained for the removal of chemical oxygen demand removal observed (Fig. 9) although the reduction trend for each dose especially once 32g. Chemical oxygen demand removal was -40.8% with a mass coagulant dose of 8g at 10 mg/L. The removal decreased dramatically to -88.9 for the 15 mg/L dose and increased at the 20 mg/L dose by -42.0% but decreased again to -127.1% at the 25 mg/L dose for 8g. The results show that there is a trend of decreasing demand for chemical removal as the coagulant dose increases for 24g and 32g, possibly due to the excess mass causing the coagulant performance to weaken.

Excessive coagulant concentrations can interfere with the aggregation process by destabilizing already formed flocs or preventing the formation of larger, denser flocs, thereby inhibiting the settling or filtration of suspended particles and reducing the overall effectiveness of the treatment process [20]. Additionally, when a coagulant is overdosed, there may be an excess of unreacted coagulant ions remaining in the water, which can maintain a charge in the solution and prevent effective particle aggregation and settling [21].

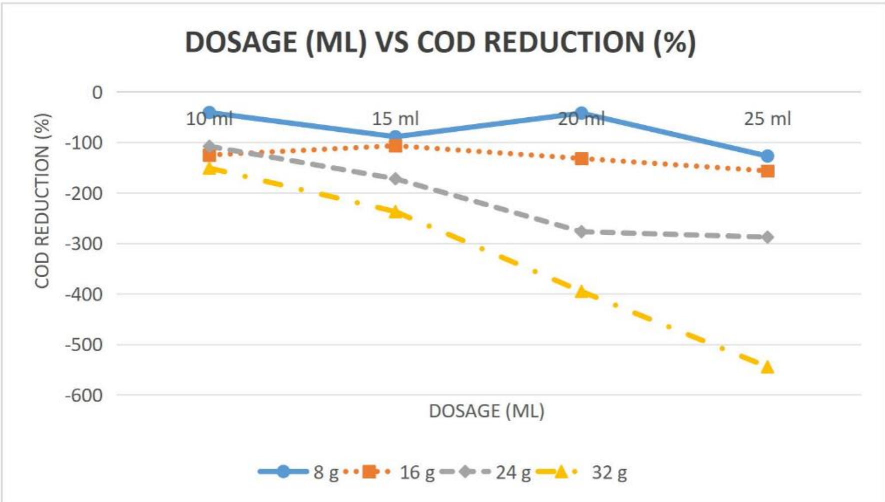


Fig 9 *Dosage (mL) vs COD Removal (%)*

3.3.3 Color Removal

A similar decreasing trend was obtained for colour removal observed in Fig. 10, although the removal was not as high as for COD removal. Colour removal at 8g was 17.14% with a coagulant dose of 10 mg/L. The removal decreased to -57.14%, - 102.86%, and -160.87% for 15, 20, and 25 mg/L, respectively.

The negative data factor in the dose versus colour removal percentage graph is due to the inverse of the relationship, where higher doses result in lower colour removal percentages, indicating that as the dose of a particular substance or treatment increases, the effectiveness in removing colour decreases. Conversely, this indicates that lower doses are more effective for colour removal, highlighting the optimal range for doses that maximise colour removal efficiency while avoiding the counterproductive effects observed at higher levels [22].

This is proven only for the mass of 8g with a coagulant dose of 10 mg/L, which shows a positive value, but for the next mass, which is 16g, 24 g, and 32 g, it shows a negative value because it is not productive. Therefore, only 8 g of mass proved to be effective for colour removal.

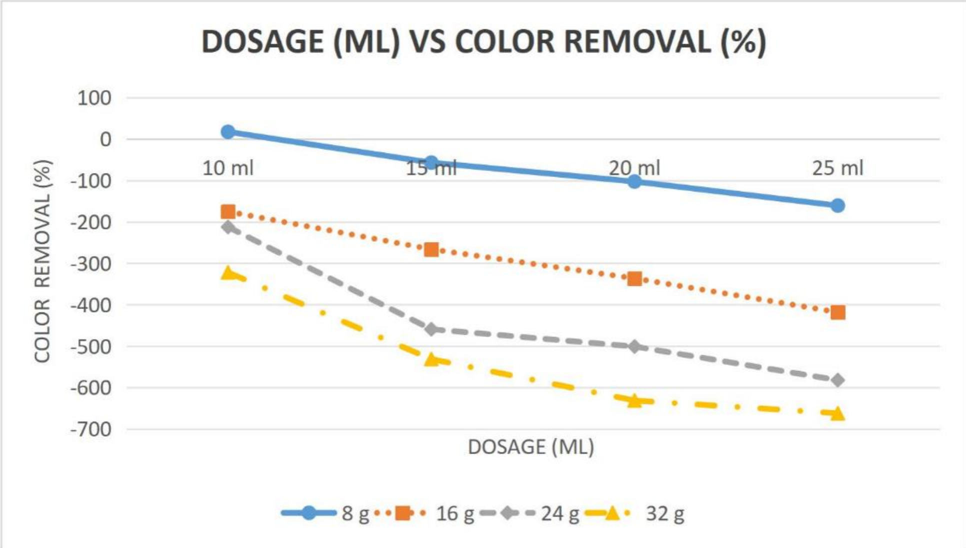


Fig. 10 *Dosage (mL) vs Color Removal (%)*

3.3.4 pH

In the coagulation process, the pH of the solution has been identified as the most important parameter because it affects the surface charge of the coagulant and also the stabilization of the suspension [23]. The pH data value so far is stable at a pH range of 7.5 to 9 as in Fig. 11. This shows that the pH value is neutral and still safe because it is not too acidic. The observed pH range of 7.5 to 9 is considered alkali and safe for most coagulation processes. This range ensures that the water is neither too acidic nor too basic, minimizing the risk of corrosion or scaling in treatment infrastructure. Maintaining a neutral pH also ensures that the treated water is safe for human consumption and meets regulatory standards.

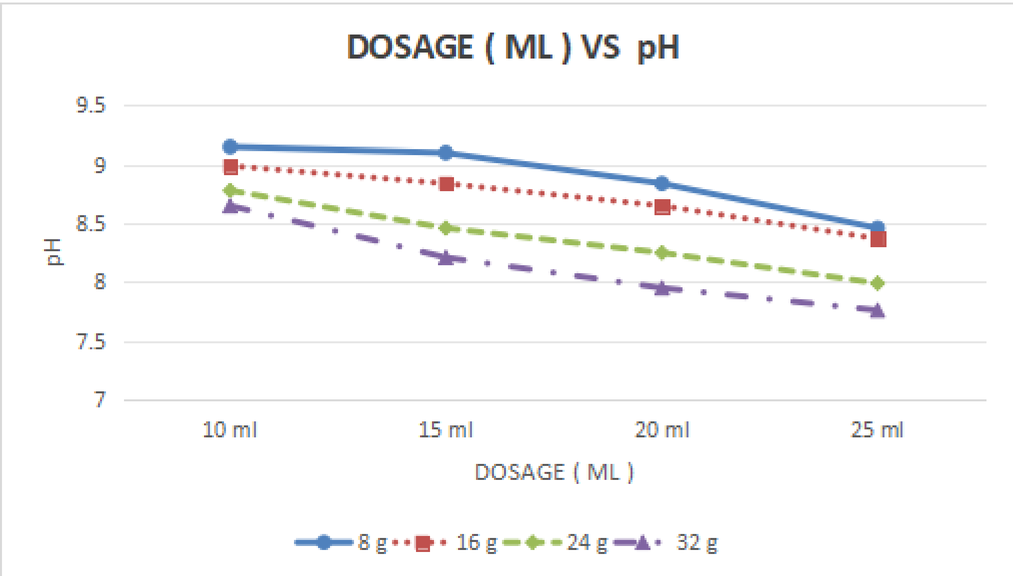


Fig. 11 *Dosage (mL) vs pH*

4. Conclusion

The think about establishes that longan seed powder can be used as a normal coagulant in the treatment of material wastewater hence encouraging the use of sustainable and low-cost alternatives for material wastewater. Using X-ray Diffraction (XRD) analysis, a major top was revealed at 2θ = 23° demonstrating a crystalline grid structure, whereas Scanning Electron Microscopy (SEM)revealed the seeds compressed porosity, ideal for carbon trapping. The coagulant was effective in reducing all the turbidity with the optimum dosage at 8g and the specified Chemical Oxygen Demand (COD) elimination rates at 1M indicator of 20-30%. Nevertheless, the higher masses were detrimental to proficiency owing to molecule swarming. These findings describe the prospects of longan seeds in reducing wastewater pollution grades by decreasing the turbidity and COD, thus enhancing sustainable wastewater management practices and reducing of risks of biochemical pollution. The study's implications promote sustainable waste management practices, offer a cost-effective alternative for wastewater treatment, and reduce environmental contamination risks. It is recommended that further research be conducted to optimize the application methods and concentrations of longan seeds for different types of wastewater. Additionally, scaling up the usage of longan seeds in industrial wastewater treatment plants could be explored to validate their effectiveness on a larger scale.

Acknowledgement

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through TIER 1 (Vot Q405). In addition, the authors would also like to thank the Centre of Diploma Studies, Universiti Tun Hussein Onn Malaysia (UTHM) for their assistance throughout the research.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Authors Contribution

The author s confirm contribution to the paper as follows: ***study conception and design:*** *Norhayati Ngadiman;* ***data collection:*** *Nur Atiqah Alya Binti Kamarulzaman, Mawarni Binti Jamaluddin, Nurul Iman Binti Othman;* ***analysis and interpretation:*** *Norhayati Ngadiman, Nur Atiqah Alya Binti Kamarulzaman, Mawarni Binti Jamaluddin, Nurul Iman Binti Othman;* ***draft manuscript preparation:*** *Norhayati Ngadiman, Nur Atiqah Alya Binti Kamarulzaman, Mawarni Binti Jamaluddin, Nurul Iman Binti Othman. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] C. Zamora-Ledezma, D. Negrete-Bolagay, F. Figueroa, E. Zamora-Ledezma, M. Ni, F. Alexis, and V. H. Guerrero, "*Heavy metal water pollution: A fresh look about hazards, novel and conventional remediation methods*," Environmental Technology & Innovation, vol. 22, pp. 101504, 2021.

[2] R. Al-Tohamy, S. S. Ali, F. Li, K. M. Okasha, Y. A. G. Mahmoud, T. Elsamahy, H. Jiao, Y. Fu, and J. Sun, "*A critical review on the treatment of dye-containing wastewater: Ecotoxicological and health concerns of textile dyes and possible remediation approaches for environmental safety*," Ecotoxicology and Environmental Safety, vol. 231, pp. 113160, 2022.

[3] A. Azanaw, B. Birlie, B. Teshome, and M. Jemberie, "*Textile effluent treatment methods and eco-friendly resolution of textile wastewater*," Case Studies in Chemical and Environmental Engineering, vol. 6, 2022.

[4] A. Amr, "*Recent Advancements in Plant-Based Natural Coagulant Application in the Water and Wastewater Coagulation-Flocculation Process: Challenges and Future Perspectives*," Global NEST Journal, 2022.

[5] T. Tong and M. Elimelech, "*The Global Rise of Zero Liquid Discharge for Wastewater Management: Drivers, Technologies, and Future Directions*," Environmental Science & Technology, vol. 50, no. 13, pp. 6846–6855, 2016.

[6] M. Zajdi and U. Aleksander-Kwaterczak, "*Wastewater Treatment Methods for Effluents from the Confectionery Industry – an Overview*," Journal of Ecological Engineering, vol. 20, no. 9, pp. 293–304, 2019.

[7] J. A. Pérez-Casas, A. A. Zaldívar-Cadena, A. Álvarez-Mendez, J. J. Ruiz-Valdés, S. M. De La Parra-Arciniega, D. C. López-Pérez, and A. I. Sánchez-Vázquez, "Sugarcane Bagasse Ash as an Alternative Source of Silicon Dioxide in Sodium Silicate Synthesis. Materials, vol. 16, no. 18, pp. 6327, 2023.

[8] F. Younas, A. Mustafa, Z. U. R. Farooqi, X. Wang, S. Younas, W. Mohy-Ud-Din, Hameed, et al., "*Current and Emerging Adsorbent Technologies for Wastewater Treatment: Trends, Limitations, and Environmental Implications*," Water, vol. 13, no. 2, pp. 215, 2021.

[9] M. R. Goyal and S. Kulkarni, "Advances in Green and Sustainable Nanomaterials: Applications in Energy, Biomedicine, Agriculture, and Environmental Science," CRC Press, 2023.

[10] M. Abd Mutalib, M. A. Rahman, M. H. D. Othman, A. F. Ismail and J. Jaafar, “Scanning Electron Microscopy (SEM) and Energy-Dispersive X-Ray (EDX) Spectroscopy,” In Membrane Characterization, pp. 161–179, 2017.
[11] B. Tian, S. Wang, J. Wang, F. Feng, L. Xu, X. Ma and Y. Tian, “*A comprehensive evaluation on thermo-chemical potential of longan waste for the production of chemicals and carbon materials*,” Fuel, vol. 334, 2023.
[12] E. Y. Yang, Y. S. Han, and K. H. Sim, “*Characterisation of nutritional, physiochemical, and mineral compositions of aril and seed of longan fruit (Dimocarpus longan L.),*” International Food Research Journal, vol. 28, no. 1, pp. 91–101, 2021.
[13] F. Mcyotto, Q. Wei, D. K. Macharia, M. Huang, C. Shen and C. W. Chow, “*Effect of dye structure on color removal efficiency by coagulation*,” Chemical Engineering Journal, vol. 405, pp. 126674, 2021.
[14] X. Lu, X. Gu and Y. Shi, “*A review on lignin antioxidants: Their sources, isolations, antioxidant activities and various applications*,” International Journal of Biological Macromolecules, vol. 210, pp. 716–741, 2022.
[15] M. Tudu and A. Samanta, “*Natural polysaccharides: Chemical properties and application in pharmaceutical formulations*,” European Polymer Journal, vol. 184, no. 111801, pp. 2023.
[16] S. Shi, W. Wang, L. Liu, B. Shu, Y. Wei, D. Jue, J. Fu, J. Xie and C. Liu, “*Physico-chemical properties of longan fruit during development and ripening*,” Scientia Horticulturae, vol. 207, pp. 160–167, 2016.
[17] X. Zhang, S. Guo, C. T. Ho and N. Bai, “*Phytochemical constituents and biological activities of longan (Dimocarpus longan Lour.) fruit: a review*,” Food Science and Human Wellness, vol. 9, no. 2, pp. 95–102, 2020.
[18] Y. Y. Tang, X. M. He, J. Sun, C. B. Li, L. Li, J. F. Sheng, Xin, et al., “*Polyphenols and Alkaloids in Byproducts of Longan Fruits (Dimocarpus Longan Lour.) and Their Bioactivities*,” Molecules, vol. 24, no. 6, pp. 1186, 2019.
[19] A. A. K. Dhrubo, M. Jannat, and M. S. Hossain, “*Enhancing the performance of coagulants for wastewater treatment by varying and optimizing the experimental parameters*,” Journal of Water Process Engineering, vol. 55, pp. 104144, 2023.
[20] G. Vijayaraghavan, T. Sivakumar, and A. Vimal Kumar, "*Application of plant based coagulants for waste water treatment*," International Journal of Advanced Engineering Research and Studies, 2011.
[21] S. Hedayati, R. Sadeghi, and G. Moussavi, "*Optimization of coagulation-flocculation treatment process for Turkmenchay river water using aluminum sulfate: Kinetic and statistical analysis*," Environmental Progress & Sustainable Energy, vol. 38, no. 5, pp. 20368, 2019.
[22] M. Sillanpää, M. C. Ncibi, A. Matilainen, and M. Vepsäläinen, "*Removal of natural organic matter in drinking water treatment by coagulation: A comprehensive review*," Chemosphere, vol. 190, pp. 54-71, 2018.
[23] C. S. Rodrigues, L. M. Madeira, and R. A. Boaventura, “*Treatment of textile dye wastewaters using ferrous sulphate in a chemical coagulation/flocculation process*,” Environmental technology, vol. 34, no. 6, pp. 719-729, 2013.
[24] H. Patel, and R. T. Vashi, “*Removal of Congo Red dye from its aqueous solution using natural coagulants*,” Journal of Saudi Chemical Society, vol. 16, no. 2, pp. 131–136, 2012.