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PERFORMANCE OF SAGO WASTE IN REDUCING TURBIDITY AND SUSPENDED SOLIDS IN AQUACULTURE WASTEWATER

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Abstract:

Aquaculture wastewater often contains high levels of suspended solids and turbidity, which may negatively affect water quality and aquatic ecosystems if discharged without treatment. Although chemical coagulants are effective for suspended solids removal, their use is associated with environmental, economic, and sludge management concerns. However, limited studies have explored the use of sago waste as a natural coagulant for aquaculture wastewater treatment, particularly for turbidity and total suspended solids (TSS) removal. This study investigates the effectiveness of sago waste as a natural coagulant for aquaculture wastewater treatment and examines the effect of coagulant dosage on turbidity and TSS removal. Jar test experiments were conducted using aquaculture wastewater treated with sago waste at dosages ranging from 0.1 to 10 mg/L. Turbidity and TSS concentrations were measured before and after treatment to determine removal efficiency. The results showed that sago waste was able to reduce turbidity and TSS at all tested dosages. Turbidity removal efficiency increased from 16.97% at 0.1 mg/L to a maximum of 20.50% at 10 mg/L, indicating the optimal dosage for turbidity removal at 10 mg/L, while TSS removal showed limited variation, with the optimal dosage observed at 1 mg/L, achieving a removal efficiency of 13.86%. In conclusion, sago waste demonstrated greater effectiveness in turbidity reduction than in TSS removal and can serve as a sustainable and low-cost natural coagulant for preliminary treatment of aquaculture wastewater.

Keyword:

Aquaculture Wastewater, Natural Coagulant, Sago Waste, Turbidity Removal, Total Suspended Solids

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Introduction

Aquaculture production has expanded rapidly in recent decades to meet the increasing demand for aquatic protein. However, this expansion has been accompanied by the generation of wastewater containing elevated levels of suspended solids, fine particulates, and organic matter. High turbidity and total suspended solids (TSS) in aquaculture effluents can reduce light penetration, disrupt photosynthetic activity, and negatively affect aquatic ecosystems if discharged without adequate treatment. In addition, excessive suspended solids may impair water reuse within aquaculture systems and contribute to the deterioration of receiving water bodies (Barraza-Guardado et al., 2013). Coagulation–flocculation is commonly applied as a primary method for the removal of suspended particles due to its operational simplicity and effectiveness. Conventional chemical coagulants such as aluminium sulphate and ferric salts have been widely used. However, their application is often associated with disadvantages including high chemical demand, generation of non-biodegradable sludge, potential residual metal content, and increasing sludge management costs (Hussaini Jagaba, 2018). These concerns have encouraged the exploration of alternative treatment approaches based on environmentally friendly and sustainable materials.

In recent years, natural coagulants derived from biopolymer sources have gained increasing attention as potential substitutes for chemical coagulants. Studies have reported *Moringa oleifera* seed extract and chitosan were utilized as natural coagulants, achieving 47% and 84% turbidity removal, respectively. Chitosan demonstrated superior performance in removing chemical oxygen demand, total suspended solids, volatile solids, and phosphate content compared to Moringa oleifera seed extract (Tong et al., 2022). Other plant-derived materials, such as *Opuntia ficus-indica* fruit peel mucilage as a natural coagulant, demonstrating a maximum turbidity removal of 82.7% and colour removal of 71.82% (Otálora et al., 2022). These findings indicate that natural coagulants can provide acceptable removal performance while offering advantages in terms of biodegradability and environmental compatibility.

In Malaysia and several parts of Southeast Asia, the sago starch industry generates large quantities of sago waste, a fibrous residue produced during starch extraction. This by-product is often underutilised or disposed of as waste, leading to environmental concerns. Sago waste contains polysaccharides and lignocellulosic components that may facilitate particle destabilisation and aggregation through adsorption and bridging mechanisms. Despite its availability and potential functionality, limited studies have examined the application of sago waste as a natural coagulant for wastewater treatment, particularly for aquaculture effluents (Wan Kamar et al., 2015). However, limited studies have specifically investigated its application for turbidity and TSS removal in aquaculture wastewater, highlighting a research gap in this area.

Furthermore, existing research on natural coagulants has largely focused on drinking water and municipal wastewater, with comparatively fewer studies addressing aquaculture wastewater, which is characterised by high particulate content and variable organic loading. The lack of applied studies evaluating the influence of natural coagulant dosage on turbidity and TSS removal in aquaculture wastewater represents a practical research gap, especially for low-cost treatment options suitable for small- and medium-scale aquaculture operations. Therefore, this study investigates the effectiveness of sago waste as a natural coagulant for aquaculture wastewater treatment and examines the effect of coagulant dosage on turbidity and total suspended solids (TSS) removal

Literature Review

The application of coagulation–flocculation for the removal of suspended particles has been widely reported as an effective approach in water and wastewater treatment. This process functions primarily through particle destabilisation, aggregation, and subsequent sedimentation of colloidal matter. While chemical coagulants such as aluminium sulphate and ferric chloride have demonstrated high removal efficiencies, their long-term use has raised concerns related to chemical dependency, sludge toxicity, and environmental sustainability (Ho et al., 2020). As a result, increasing research attention has been directed toward the development of natural and biodegradable coagulants derived from renewable resources.

Natural coagulants are generally obtained from plant-based materials, animal-derived, or microbial products, and their coagulation performance is often attributed to the presence of functional groups such as hydroxyl, carboxyl, and amine groups (Kristianto et al., 2025). One of the most extensively studied natural coagulants is M. oleifera seed extract, which contains water-soluble proteins capable of neutralising negatively charged particles. Numerous studies have reported its effectiveness in turbidity removal from surface water and low-strength wastewater. However, the availability of M. oleifera seeds and the need for extraction processes may limit its large-scale application in certain regions (Abouzied et al., 2023).

Chitosan, a coagulant derived from chitin, has also been widely investigated as a natural coagulant and coagulant aid. Due to its cationic nature and high molecular weight, chitosan is effective in destabilising suspended particles through charge neutralisation and bridging mechanisms. Studies have demonstrated that chitosan can achieve significant turbidity and TSS removal at relatively low dosages; however, its relatively high production cost and dependence on crustacean waste sources may restrict its widespread use, particularly in low-cost treatment applications (Malhotra & Gautam, 2024).

In addition to protein- and polymer-based coagulants, several agricultural and plant-derived wastes have been explored as alternative natural coagulants. The use of natural materials such as cactus mucilage, banana peel, cassava starch, and rice husk derivatives for water treatment has gained attention due to their cost-effectiveness and environmental benefits. These materials have demonstrated varying efficiencies in removing turbidity and suspended solids, influenced by factors such as wastewater characteristics and coagulant dosage (Azamzam et al., 2022; Lemma et al., 2024).

With respect to aquaculture wastewater, relatively fewer studies have focused on the application of natural coagulants compared to drinking water and municipal wastewater treatment. Aquaculture effluents are typically characterised by high levels of suspended solids

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originating from uneaten feed, faecal matter, and microbial flocs (Chen et al., 1997). Previous studies have reported that natural coagulants may achieve moderate turbidity and TSS removal in aquaculture systems, particularly when applied as a pre-treatment or polishing step rather than as a standalone primary treatment. These findings suggest that natural coagulants can contribute to improved water clarity while maintaining environmental compatibility (Tomasi et al., 2025).

The sago starch industry generates substantial quantities of sago waste, a fibrous residue remaining after starch extraction. This by-product is rich in polysaccharides and lignocellulosic components, which are known to contribute to coagulation through adsorption and inter-particle bridging mechanisms. Although sago waste has been investigated for applications such as animal feed, bio-composite materials, and energy recovery, its utilisation in wastewater treatment remains limited. In particular, there is a lack of experimental data evaluating the influence of sago waste dosage on turbidity and TSS removal from aquaculture wastewater (Wan Kamar et al., 2015).

Based on the reviewed literature, it is evident that while numerous natural coagulants have been explored, the performance of agro-industrial residues is highly dependent on material characteristics and dosage levels. The limited application of sago waste in aquaculture wastewater treatment highlights a research gap that warrants investigation. Therefore, evaluating the effect of sago waste dosage on turbidity and TSS removal can provide valuable baseline information and support the development of sustainable, low-cost treatment strategies for aquaculture wastewater management.

Methodology

Collection of Aquaculture Wastewater

Aquaculture wastewater used in this study was collected from a freshwater aquaculture local company located in Negeri Sembilan, Malaysia. The wastewater was transferred into clean containers immediately after collection to minimise external contamination. To preserve the original characteristics of the wastewater prior to experimental analysis, the samples were stored in a chiller at low temperature until further use. Chilled storage was applied to retard biological activity and microbial degradation, which could otherwise alter key water quality parameters such as turbidity and total suspended solids over time. This approach ensured that the wastewater characteristics remained relatively stable throughout the experimental period, allowing the observed changes in turbidity and TSS to be attributed primarily to the effect of sago waste dosage rather than sample deterioration or uncontrolled environmental factors (Amosa et al., 2016).

Preparation of Sago Waste as Natural Coagulant

Sago waste used in this study was collected from a local village in Bachok, Kelantan, Malaysia, where sago residue is commonly reused as animal feed for livestock such as goats, ducks, and cattle. Prior to its application as a natural coagulant, the raw sago waste was cleaned using tap water to remove dirt, soil particles, and other visible impurities. This cleaning step was necessary to minimise the presence of foreign materials that could interfere with the coagulation process or affect the accuracy of water quality measurements. After washing, the sago waste was dried in an oven at 60 °C for 24 hours to ensure complete moisture removal.

Drying to a constant condition was important to improve material stability and to allow accurate dosage preparation during the coagulation experiments. The dried material was subsequently ground using a laboratory grinder to produce fine particles. The resulting sago waste powder was stored in airtight containers and used directly in the coagulation–flocculation experiments without any chemical or thermal modification. To prepare a coagulant stock solution, a known mass of sago waste powder was mixed with distilled water and stirred for 30 min to ensure homogeneous dispersion. The mixture was then filtered using 10-µm filter paper, and the filtrate (sago waste coagulant stock) was stored in clean bottles prior to jar test experiments (Ahmad et al., 2021).

Experiment of Jar Test

Sago waste Jar tests were conducted using five 1000 mL beakers. For each run, 500 mL of aquaculture wastewater was added into each beaker, followed by the addition of prepared sago waste coagulant stock solution. The operational conditions were fixed at 180 rpm for 3 min (rapid mixing) followed by 10 rpm for 20 min (slow mixing), and a 30 min settling time before sampling. After settling, supernatant was collected carefully for turbidity and TSS analysis. To standardise sampling and minimise disturbance of settled flocs, a 25-mL supernatant sample was withdrawn at approximately 5 cm below the water surface.

Removal Calculation

The removal efficiency for turbidity and TSS was calculated by comparing the initial concentration of the untreated aquaculture wastewater with the final concentration after coagulation–flocculation treatment. The percentage removal was determined using Equation (1):

$$Removal\ Efficiency\ (\%) = \left(\frac{C_o - C_f}{C_o}\right) x\ 100\% \qquad \text{....... Equation 1}$$

where C_o is the initial turbidity (NTU) or initial TSS concentration (mg/L) of the untreated wastewater, and C_f is the final turbidity (NTU) or final TSS concentration (mg/L) measured after treatment at a given sago waste dosage. This calculation was applied consistently for all dosage conditions to evaluate the effect of sago waste dosage on turbidity and TSS removal performance.

Results and Discussion

The performance of sago waste as a natural coagulant for aquaculture wastewater treatment was evaluated based on turbidity and TSS removal at different coagulant dosages. The results demonstrate that the application of sago waste led to measurable reductions in both turbidity and TSS, with removal efficiencies influenced by the applied dosage.

Effect of Sago Waste Dosage on Turbidity Removal

The effect of sago waste dosage on turbidity removal is presented in Figure 1, which shows both the final turbidity values and the corresponding removal efficiencies. The untreated aquaculture wastewater exhibited a high initial turbidity of approximately 510 ±1.53 NTU, indicating a significant presence of fine suspended and colloidal particles. As shown in Figure 1, the addition of sago waste resulted in turbidity reduction at all tested dosages, confirming its ability to promote particle aggregation.

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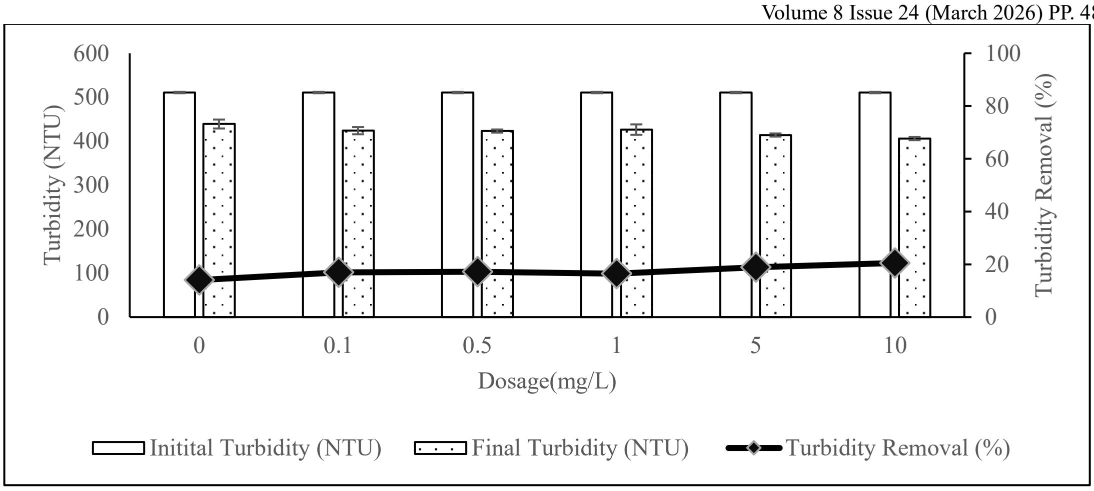

Figure 1: Effect of Sago Waste Dosage on Turbidity Removal Efficiency in Aquaculture Wastewater

At lower dosages of 0.1 mg/L and 0.5 mg/L, Figure 1 shows a modest reduction in turbidity, with removal efficiencies of 16.97% and 17.17%, respectively. The relatively small difference between these values indicates that increasing the dosage within this low range did not substantially enhance turbidity removal. This suggests that only partial destabilisation of suspended particles occurred, resulting in limited floc formation. When the dosage was increased to 1 mg/L, Figure 1 shows a slight increase in final turbidity and a corresponding decrease in removal efficiency to 16.31%. This non-linear behaviour suggests that the coagulation process was not fully effective at this dosage, possibly due to the formation of weak or unstable flocs. Such behaviour is commonly observed in natural coagulant systems, where dosage increments do not always lead to proportional improvements in removal performance. A clearer improvement in turbidity removal is observed at higher dosages of 5 mg/L and 10 mg/L, as shown in Figure 1. At these dosages, turbidity removal efficiencies increased to 18.93% and 20.50%, respectively, with the optimal dosage for turbidity removal observed at 10 mg/L. The downward trend in final turbidity values indicates enhanced particle aggregation and sedimentation, which may be attributed to the increased availability of active sites on the sago waste particles that promote adsorption and inter-particle bridging mechanisms (Choy et al., 2015). Although the overall turbidity reduction was moderate, the increasing removal trend with dosage is consistent with findings reported for other untreated natural coagulants in the literature. This moderate removal efficiency may be attributed to the unmodified nature of the sago waste, which limits the availability of active functional groups required for effective charge neutralisation and floc formation. These results indicate that sago waste has potential for partial clarification or pre-treatment applications in aquaculture wastewater treatment.

The turbidity removal trend observed in this study is consistent with findings reported in previous studies on untreated natural coagulants. A study reported that natural coagulants often exhibit gradual improvements in turbidity removal with increasing dosage, particularly when applied in their raw or minimally processed form. Similar dosage-dependent behaviour has been observed for M. oleifera seed powder, where low dosages resulted in limited turbidity reduction, while higher dosages improved removal efficiency due to enhanced particle destabilisation (Ismi Khairunnissa Ariani et al., 2024). In another study involving cactus mucilage as a natural coagulant, moderate turbidity removal was reported when the material was used without chemical extraction. The authors noted that untreated natural coagulants generally achieve lower turbidity removal compared to chemical coagulants, but their

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performance remains acceptable for pre-treatment applications. The turbidity removal efficiency of up to 20.50% achieved using sago waste in this study falls within the range reported for similar agricultural-based natural coagulants, supporting its potential applicability (Otálora et al., 2022).

Effect of Sago Waste Dosage on TSS Removal

The effect of sago waste dosage on TSS removal is illustrated in Figure 2. The initial TSS concentration of the untreated wastewater was approximately 505 ±8.89 mg/L, reflecting the high solids content typically associated with aquaculture effluents. As shown in Figure 2, the application of sago waste resulted in a reduction in TSS concentration at all tested dosages, however the overall removal efficiencies remained relatively low.

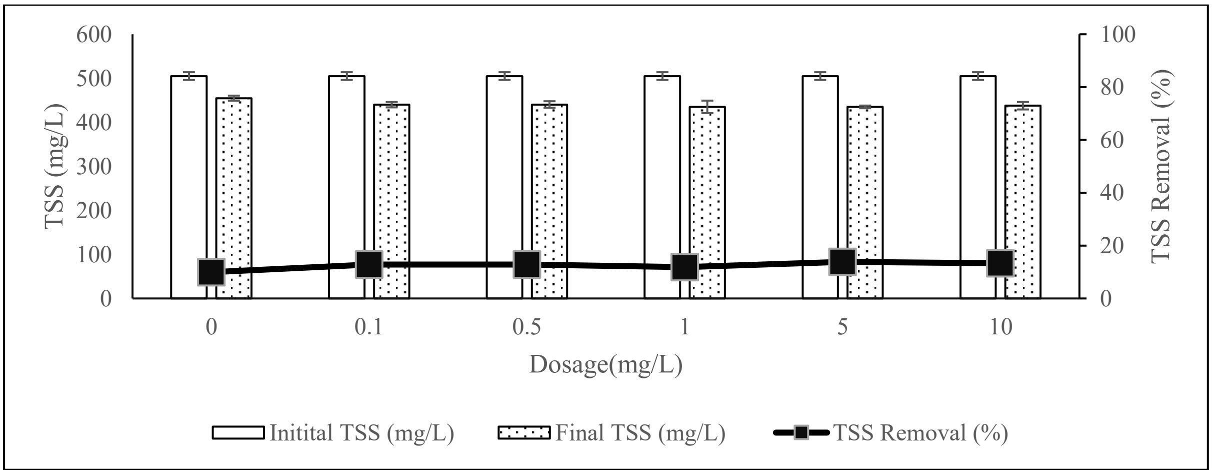

Figure 2: Effect of Sago Waste Dosage on TSS Removal Efficiency in Aquaculture Wastewater

At dosages of 0.1 mg/L and 0.5 mg/L, Figure 2 shows TSS removal efficiencies of 12.87% and 12.80%, respectively, indicating minimal improvement with dosage increase at low levels. When the dosage was increased to 1 mg/L and 5 mg/L, TSS removal efficiencies increased slightly to 13.86% and 13.85%, respectively, with the optimal dosage for TSS removal observed at 1 mg/L. This suggests that higher dosages provided marginal improvement in suspended solids aggregation. At the highest dosage tested (10 mg/L), Figure 2 shows a slight decrease in TSS removal efficiency to 13.31%, indicating that further dosage increase did not enhance solids removal. The relatively flat trend across all dosages suggests that TSS removal using sago waste is less sensitive to dosage variation compared to turbidity removal. This may be due to the inability of the formed flocs to effectively capture and settle larger or denser suspended particles.

The moderate TSS removal observed in this study is consistent with findings reported for other untreated agricultural-based natural coagulants. The study found papaya seed powder achieved 66.67% TSS removal, while banana peel powder reached 45.45%. This contrasts with previous findings of untreated agricultural coagulants, which reported TSS removal efficiencies below 20%, indicating higher effectiveness of processed coagulants (Maurya & Daverey, 2018). Similarly, studies involving chitosan and natural coagulants have shown that while turbidity removal can be significant, TSS removal often remains limited unless chemical modification or coagulant aids are applied. The TSS removal efficiencies of approximately 13–14% achieved using sago waste in this study align with these reported trends. A study done by Iber et al. (2023) reported that 69.49% TSS removal using chitosan at 8.75 mg/L dosage, which significantly exceeds the 13–14% TSS removal reported with sago waste, indicating that chitosan is more effective in TSS removal from aquaculture wastewater and a report by Wan Kamar et al., (2015) stated an 82% removal rate of suspended solids (SS) using sago starch as a coagulant, which significantly exceeds the 13–14% TSS removal efficiencies. This comparison suggests that the observed TSS removal performance is reasonable given the natural, unmodified nature of the sago waste used.

Overall, the results indicate that sago waste exhibited limited effectiveness in removing total suspended solids (TSS) from aquaculture wastewater. The TSS removal efficiency increased slightly from 12.87% at 0.1 mg/L to a maximum of 13.86% at 1 mg/L, with no substantial improvement observed at higher dosages, as illustrated in Figure 2. The relatively flat trend across all dosages suggests that TSS removal using sago waste is less sensitive to dosage variation compared to turbidity removal. This may be due to the limited ability of the formed flocs to effectively capture and settle larger or denser suspended particles, indicating that sago waste is more effective for fine particle removal rather than bulk solids removal.

Conclusion

This study evaluated the use of sago waste as a natural coagulant for the treatment of aquaculture wastewater, focusing on the effect of dosage on turbidity and TSS removal. The results showed that sago waste was able to reduce turbidity at all tested dosages. Turbidity removal efficiency increased from 16.97% at 0.1 mg/L to a maximum of 20.50% at 10 mg/L, indicating the optimal dosage for turbidity removal at 10 mg/L. This indicates that higher dosages were more effective in improving turbidity reduction. In contrast, TSS removal showed only slight variation with dosage. The optimal dosage for TSS removal was observed at 1 mg/L, with a removal efficiency of 13.86%, while increasing the dosage beyond this level did not result in further improvement. This suggests that sago waste is more effective in removing fine suspended and colloidal particles contributing to turbidity than in removing larger suspended solids. Overall, although the removal efficiencies achieved were moderate, the performance trends observed are consistent with those reported for other untreated agricultural-based natural coagulants. These findings suggest that sago waste can serve as a sustainable and low-cost natural coagulant for preliminary treatment of aquaculture wastewater, particularly in enhancing turbidity reduction while providing moderate TSS removal.

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References

Abouzied et al., A. H. (2023). Applying Moringa oleifera Extract in Water Treatment as a Natural Coagulant to Remove Turbidity and Algae. *Egyptian Journal of Aquatic Biology and Fisheries*, 27(5), 1121–1131. https://doi.org/10.21608/ejabf.2023.323750

Ahmad, A., Abdullah, S. R. S., Hasan, H. A., Othman, A. R., & Ismail, N. ’Izzati. (2021). Plant-based versus metal-based coagulants in aquaculture wastewater treatment: Effect of mass ratio and settling time. *Journal of Water Process Engineering*, 43, 102269. https://doi.org/10.1016/j.jwpe.2021.102269

Amosa, M. K., Jami, M. S., Alkhatib, M. F. R., Tajari, T., Jimat, D. N., & Owolabi, R. U. (2016). Turbidity and suspended solids removal from high-strength wastewater using high surface area adsorbent: Mechanistic pathway and statistical analysis. *Cogent Engineering*, 3(1), 1162384. https://doi.org/10.1080/23311916.2016.1162384

Azamzam, A. A., Rafatullah, M., Yahya, E. B., Ahmad, M. I., Lalung, J., Alam, M., & Siddiqui, M. R. (2022). Enhancing the Efficiency of Banana Peel Bio-Coagulant in Turbid and River Water Treatment Applications. *Water*, 14(16), 2473. https://doi.org/10.3390/w14162473

Barraza-Guardado, R. H., Arreola-Lizárraga, J. A., López-Torres, M. A., Casillas-Hernández, R., Miranda-Baeza, A., Magallón-Barrajas, F., & Ibarra-Gámez, C. (2013). Effluents of Shrimp Farms and Its Influence on the Coastal Ecosystems of Bahía de Kino, Mexico. *The Scientific World Journal*, 2013(1). https://doi.org/10.1155/2013/306370

Chen, S., Coffin, D. E., & Malone, R. F. (1997). Sludge Production and Management for Recirculating Aquacultural Systems. *Journal of the World Aquaculture Society*, 28(4), 303–315. https://doi.org/10.1111/j.1749-7345.1997.tb00278.x

Choy, S. Y., Prasad, K. M. N., Wu, T. Y., & Ramanan, R. N. (2015). A review on common vegetables and legumes as promising plant-based natural coagulants in water clarification. International *Journal of Environmental Science and Technology*, 12(1), 367–390. https://doi.org/10.1007/s13762-013-0446-2

Ho, Y.-C., Chua, S.-C., & Chong, F.-K. (2020). Coagulation-Flocculation Technology in Water and Wastewater Treatment (pp. 432–457). https://doi.org/10.4018/978-1-7998-0369-0.ch018

Hussaini Jagaba, A. (2018). Wastewater Treatment Using Alum, the Combinations of Alum-Ferric Chloride, Alum-Chitosan, Alum-Zeolite and Alum- <i>Moringa Oleifera</i> as Adsorbent and Coagulant. *International Journal of Engineering Management*, 2(3), 67. https://doi.org/10.11648/j.ijem.20180203.13

Iber, B. T., Torsabo, D., Che Engku Noramalina Che Engku, C., Wahab, F., Sheikh Abdullah, S. R., Abu Hassan, H., & Kasan, N. A. (2023). A study on the recovery and characterization of suspended solid from aquaculture wastewater through coagulation/flocculation using chitosan and its viability as organic fertilizer. *Journal of Agriculture and Food Research*, 11, 100532. https://doi.org/10.1016/j.jafr.2023.100532

Ismi Khairunnissa Ariani, Riza Hudayarizka, Rahmi Yorika, & Rebecca Olfin Liery Any. (2024). Utilization of Moringa Seed Powder (Moringa Oleifera) as a Natural Coagulant for Reducing Pollution Parameters in Tofu Wastewater. *Frontier Advances in Applied Science and Engineering,* 2(1), 1–8. https://doi.org/10.59535/faase.v2i1.234

Kristianto, H., Prasetyo, S., & Sugih, A. K. (2025). Alginate as A Natural Coagulant-Aid: Advances, Challenges, and Applications. *Journal of Multidisciplinary Applied Natural Science*, 5(3), 850–868. https://doi.org/10.47352/jmans.2774-3047.287

Lemma, M., Kalsido, A. W., & Wamolo Wotee, M. (2024). Removal of river water turbidity and total dissolved solids using natural coagulants derived from banana peel and

Moringa stenopetala seed. *AQUA — Water Infrastructure, Ecosystems and Society*, 73(7), 1467–1493. https://doi.org/10.2166/aqua.2024.130

Malhotra, H., & Gautam, R. K. (2024). Biomedical Applications of Chitosan and Its Derivatives. *In Biopolymers for Biomedical Applications* (pp. 25–51). Wiley. https://doi.org/10.1002/9781119865452.ch2

Maurya, S., & Daverey, A. (2018). Evaluation of plant-based natural coagulants for municipal wastewater treatment. *3 Biotech*, 8(1), 77. https://doi.org/10.1007/s13205-018-1103-8

Otálora, M. C., Wilches-Torres, A., Lara, C. R., Gómez Castaño, J. A., & Cifuentes, G. R. (2022). Evaluation of Turbidity and Color Removal in Water Treatment: A Comparative Study between Opuntia ficus-indica Fruit Peel Mucilage and FeCl3. *Polymers*, 15(1), 217. https://doi.org/10.3390/polym15010217

Tomasi, I. T., Boaventura, R. A. R., & Botelho, C. M. S. (2025). Natural Coagulants as an Efficient Alternative to Chemical Ones for Continuous Treatment of Aquaculture Wastewater. *Applied Sciences*, 15(12), 6908. https://doi.org/10.3390/app15126908

Tong, C. Y., Yusuf, F. H. B. C., & Derek, C. J. C. (2022). Optimization of Moringa oleifera seed extract and chitosan as natural coagulant in treatment of fish farm wastewater. *Desalination and Water Treatment*, 256, 99–113. https://doi.org/10.5004/dwt.2022.28370

Wan Kamar, W. I. S., Abdul Aziz, H., & Ramli, S. F. (2015). Removal of Suspended Solids, Chemical Oxygen Demand and Color from Domestic Wastewater Using Sago Starch as Coagulant. *Applied Mechanics and Materials*, 802, 519–524. https://doi.org/10.4028/www.scientific.net/AMM.802.519