journal homepage: https://journal.pktm.com.my/

International Journal of Technical Vocational and Engineering Technology

e-SSN2710-7094, Vol. 6, No. 1 (2025)

Utilizing Chitosan Extracted From Shrimp Byproducts As A Bio-Coagulant For Treating Oily Waste Emulsions

Sunatrah Abdullahyi[1*], Leong Kok Seng[1], Sagir Alva[2]

[1]Department of Petrochemical Engineering, Polytechnic Tun Syed Nasir Syed Ismail, Johor, Malaysia

[2]Engineering Faculty, Universitas Mercu Buana, South Meruya No. 1 Kembangan, West Jakarta 11650, Indonesia

*Corresponding Author email: sunatrah@ptsn.edu.my

ARTICLE INFO
Article History:
Received 4 September 2024
Revised 7 April 2025
Accepted 20 June 2025
Published 30 June 2025

Keywords:
Coagulation;
Oily Waste Emulsion;
Chitosan.

ABSTRACT
Across sectors, the coagulation process is widely used to remove colloidal contaminants, particularly suspended particles like bacteria and organic debris. But because of their natural source and biodegradable nature, using bio-coagulants offers a more feasible option. With a monthly production range of 20 to 60 tons, this project focuses on the extraction of chitin and chitosan from shrimp waste with the goal of using chitosan as a bio-coagulant for the treatment of oily waste emulsions. The use of chemical coagulants, such as ferric chloride and aluminum sulfate, raises questions about their potential negative effects on the environment and human health. These coagulants are particularly difficult for smaller-scale enterprises to obtain. Therefore, the main goals of this project are to extract chitosan from shrimp waste and assess how well it works to remediate oily waste emulsions. Deproteinization, demineralization, and deacetylation processes are all included in the extraction process. Testing that comes after this evaluates oily wastewater by employing powdered and coarse chitosan, and coagulation processes are tested in jars. The findings demonstrate that powdered chitosan performs better than coarse forms, with an effectiveness of coagulation activity is 91.79%, fulfilling the project's goals. To improve chitosan's ability to cure oily waste emulsions, it is advised to adjust the dosage to 0.1g/ml – 0.15g/ml. This study highlights the possibility of using chitosan made from shrimp waste as an efficient and sustainable coagulation process substitute, posing a threat to traditional chemical coagulants. This strategy complies with green chemistry and sustainable industrial practices by optimizing environmental effects and utilizing natural resources.

1.0 Introduction

Chemical coagulants such as alum and ferric chloride are widely used in industrial wastewater treatment to facilitate the removal of suspended solids and other contaminants. However, their application often leads to unintended environmental consequences. One significant issue is the increase in biochemical oxygen demand (BOD), which encourages algal growth and contributes to eutrophication. The resulting algal blooms can severely degrade aquatic ecosystems by causing oxygen depletion during decomposition, as highlighted by (Akinnawo, 2023). In addition, chemical coagulants leave behind hazardous residual metal salts and may contain heavy metals like lead and mercury. These toxic substances accumulate in water bodies over time, further exacerbating eutrophication and threatening aquatic biodiversity.

Moreover, the reliance on chemical coagulants can pose logistical and economic challenges, especially for small-scale or inland industries. These entities often face difficulties in acquiring chemical supplies, making them more dependent on conventional chemical solutions, which worsens environmental degradation. The use of chemical coagulants also contributes to high sludge volumes and raises treatment costs. For instance, the treatment of palm oil mill effluent (POME) using alum can cost as much as USD 19 per cubic meter, while using polyaluminum chloride (PAC) for leachate treatment may cost up to USD 1.80 per cubic meter (Kurniawan et al., 2020). Additionally, these coagulants are associated with moderate to high toxicity levels, posing risks to both aquatic organisms and human health (Mohamed Noor et al., 2024).

Given these drawbacks, there is a growing need for sustainable alternatives such as bio-coagulants derived from natural sources. One promising material is chitosan, which can be extracted from shrimp waste. This bio-coagulant offers several environmental and economic advantages. It is biodegradable, produces significantly less toxic sludge, and has a lower ecotoxicological impact. Studies have shown that the use of chitosan in wastewater treatment can achieve up to 98% turbidity removal and up to 95% phosphorus removal in agricultural wastewater (Aguilera Flores et al., 2023). Economically, bio-coagulants like chitosan are also more viable, with the estimated treatment cost being as low as USD 0.015 per cubic meter substantially lower than that of chemical coagulants.

In light of this, the proposed project aims to harness shrimp waste to produce chitosan for use in industrial wastewater treatment. The shrimp waste will be collected from local markets and eateries in Pagoh Jaya before being processed into chitosan. In parallel, oily waste emulsion samples will be sourced from palm oil mill effluent (POME) in Pagoh to serve as test samples. This effluent contains soluble pollutants that can pose serious environmental threats if not properly treated (Masron et al., 2023). The goal is to use shrimp-derived chitosan as a bio-coagulant to remove contaminants from POME and transform it into environmentally safe effluent that can be safely reintroduced into the water cycle.

To evaluate the efficiency of the shrimp-based chitosan, various water quality parameters such as turbidity and pH will be measured before and after treatment. These results will help determine the effectiveness of chitosan in pollutant removal and its potential as a sustainable alternative in industrial wastewater treatment. The anticipated outcomes include reduced environmental impact, lower treatment costs, and minimized health risks associated with chemical coagulants. Ultimately, this project supports the broader goal of promoting eco-friendly water management practices while creating value from what would otherwise be seafood waste.

2.0 Literature review

2.1 Type of coagulant

In several industries, such as the manufacture of certain materials, wastewater treatment, and water treatment, coagulants are essential. Coagulants come in a variety of forms; these include plant-, animal-, and microorganism-based solutions (Teh, Wu, & Juan, 2014). Plant-based coagulants come from raw materials like bark, roots, and seeds. These coagulants frequently include substances with coagulation-promoting qualities, such as polysaccharides, lignins, and tannins. Moringa oleifera seeds are one example of a plant-based coagulant. These seeds are high in protein and have coagulation qualities that make them useful for treating water. Coagulants that are animal-based are made from animal products or by-products. Gelatin, which is made from animal bones and connective tissues, and albumin, which is made from egg whites, are two examples of coagulants obtained from animals (Arturi et al., 2019). Various microorganisms, including fungi and bacteria, are the source of microorganism-based coagulants. These microbes create substances like polymers and specific enzymes that could clot.

These coagulants are applicable to various processes in several industries, such as the manufacture of certain materials, wastewater treatment, and water treatment. Coagulants are essential. Furthermore, certain materials, including bioplastics, can be produced using coagulants based on microorganisms. Each of these many coagulant kinds has specific benefits and drawbacks. For instance, because they are derived from renewable resources, plant-based coagulants are frequently seen as sustainable and environmentally beneficial. Because of their makeup, animal-based coagulants may have some useful qualities, but situations, they may also give rise to ethical questions. Although they could need certain circumstances for manufacturing and purification, microorganism-based coagulants have the potential to be more effective and selective in their actions. Overall, the application and intended results determine the best coagulant, considering aspects like cost, availability, sustainability, effectiveness, and ethical issues.

Bio-coagulants derived from plant, animal, and microbial sources offer promising alternatives to conventional chemical coagulants in wastewater treatment. The comparative summary in Table 1.1 below highlights their relative effectiveness, environmental impact, cost-efficiency, and ease of application, helping to inform sustainable coagulant selection

Table 1.1: Comparative Summary of Bio-Coagulants

Bio-Coagulant Type	Source Example	Effectiveness	Cost	Environmental Impact	Ease of Use
Plant-Based	*Moringa oleifera,* cactus mucilage	Moderate to high turbidity removal (up to 90%)	Low	Biodegradable Low toxicity	Easy; simple grinding or extraction
Animal-Based	Chitosan from shrimp/crab shells	High removal of turbidity, oil, phosphorus (up to 98%)	Low to moderate	Biodegradable Valorizes seafood waste	Require chemical process (e.g. deacetylation
Microorganism-Based	Bacterial polysaccharides, Fungal biomass	Variable; specific to pollutant type	Moderate to high	Low toxicity Safe for ecosystems	Require fermentation facilities

2.2 Coagulation-Flocculation treatment

In water and wastewater treatment facilities, coagulation-flocculation is an important technique that improves treatment efficacy and economy (Zaki et al., 2023). It is employed in the production of drinking water, the treatment of dissolved organic matter and particle suspensions, and the separation of solids from industrial polymer effluents (Raissi, 2023). Chemical coagulants are added to the suspended particles to destabilize and aggregate them, and flocculants are then added to encourage the production of bigger particles known as flocs (Teh et al., 2014). One source claims that the most used method for pre-treating industrial effluent and raw water is coagulation-flocculation (Iwuozor, 2019). One treatment method that is frequently used in the processing of water and wastewater is coagulation-flocculation. According to the source, coagulation-flocculation is a useful technique for clearing water and wastewater of colloids, suspended solids, and other particles. Coagulants and flocculants are used in this treatment procedure to encourage the production of flocs, which helps remove contaminants from the water. The source also emphasizes how coagulants work by neutralizing the charges of the suspended particles, which makes it possible for them to clump together and form larger aggregates. After that, these aggregates, also known as flocs, are easily removed using filtration or sedimentation techniques.

2.3 Conventional vs. Current Technology for Oily Wastewater Treatment

Treatment of oily wastewater has advanced dramatically, moving from traditional techniques to more sophisticated technology in response to the problems presented by increasingly complicated industrial and residential wastewater streams. Historically, conventional methods including chemical treatment, coalescence, and gravity separation have been used. Because oil and water have different densities, gravity separation uses this difference to push oil to the top where it may be removed. While chemical treatment includes adding coagulants or flocculants to aggregate oil droplets, coalescence makes it simpler for small oil droplets to merge into bigger ones. Nevertheless, these techniques might not be able to treat highly emulsified oily wastewater as well as they can produce sludge, which would make disposal more difficult.

On the other hand, modern technology provides environmentally acceptable and more effective ways to treat greasy wastewater. Because it can successfully remove oil by introducing air bubbles that adhere to oil droplets and cause them to float to the surface for removal, dissolved air flotation, or DAF, is frequently employed (Yu, han, & He., 2017). Reverse osmosis and ultrafiltration are two membrane filtration techniques that remove impurities and oil from wastewater by passing it through specialized membranes. Utilizing microorganisms to break down organic compounds found in oily wastewater, biological treatment techniques including activated sludge and bioaugmentation lower the amount of oil and chemical oxygen demand (COD) (Adetunji & Olaniran, 2021). Another cutting-edge technique is electro-coagulation, which uses electrical current to destabilize pollutants and make it easier for them to be removed by flotation or precipitation.

These cutting-edge technologies have many benefits over traditional approaches. In addition to producing less secondary waste and being more adaptive to changing wastewater compositions and treatment goals, they frequently achieve greater removal efficiency. Additionally, they lessen the environmental impact of wastewater treatment procedures, which promotes environmental sustainability. However, several factors, such as the wastewater's composition, treatment goals, legal restrictions, and economic considerations, influence the choice of the best technique. In general, the continuous advancement and implementation of cutting-edge technologies are essential for enhancing the efficacy and efficiency of treating oily wastewater while guaranteeing the preservation of ecosystems and water resources.

3.0 Methodology

3.1 Chitosan Extraction Process

The extraction of chitosan from shrimp waste involves a series of chemical and physical treatments to isolate and convert chitin into chitosan. This process includes key steps such as deproteinization, demineralization, and deacetylation to ensure high-purity chitosan suitable for use as a bio-coagulant. The following flowchart in Figure 1.1 outlines the step-by-step procedure used in this study for chitosan extraction.

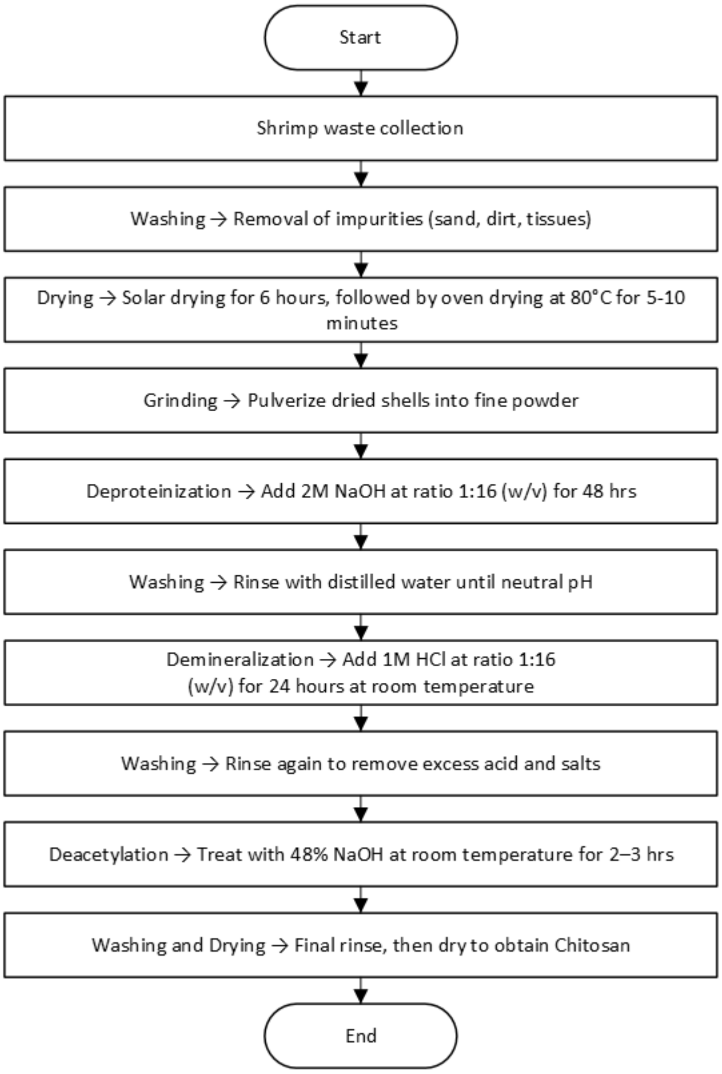

Figure 1.1: The flow chart of chitosan extraction process

3.2 Coagulation-Flocculation Process

The coagulation process involves conducting two separate tests utilizing chitosan samples in coarse and powder forms as shown in Figure 1.2. This approach was motivated by the fact that chitosan can be obtained in different physical states. The objective was to examine how these distinct forms of chitosan interact with the oily emulsion and influence the rate of reaction during the coagulation process. Both powdered and coarse chitosan treatments were applied to the oily wastewater to evaluate how well each form separates the oil and particles in the emulsion. The rate of reaction is a critical parameter to determine which form of chitosan exhibits superior performance in forming flocs and facilitating the removal of impurities from the wastewater. The process flowchart of coagulation-flocculation experiment was shown in Figure 1.3 below.

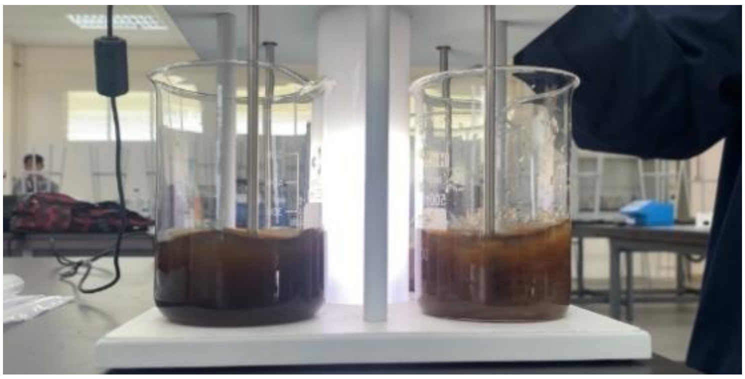

Figure 1.2: Coagulation-flocculation process

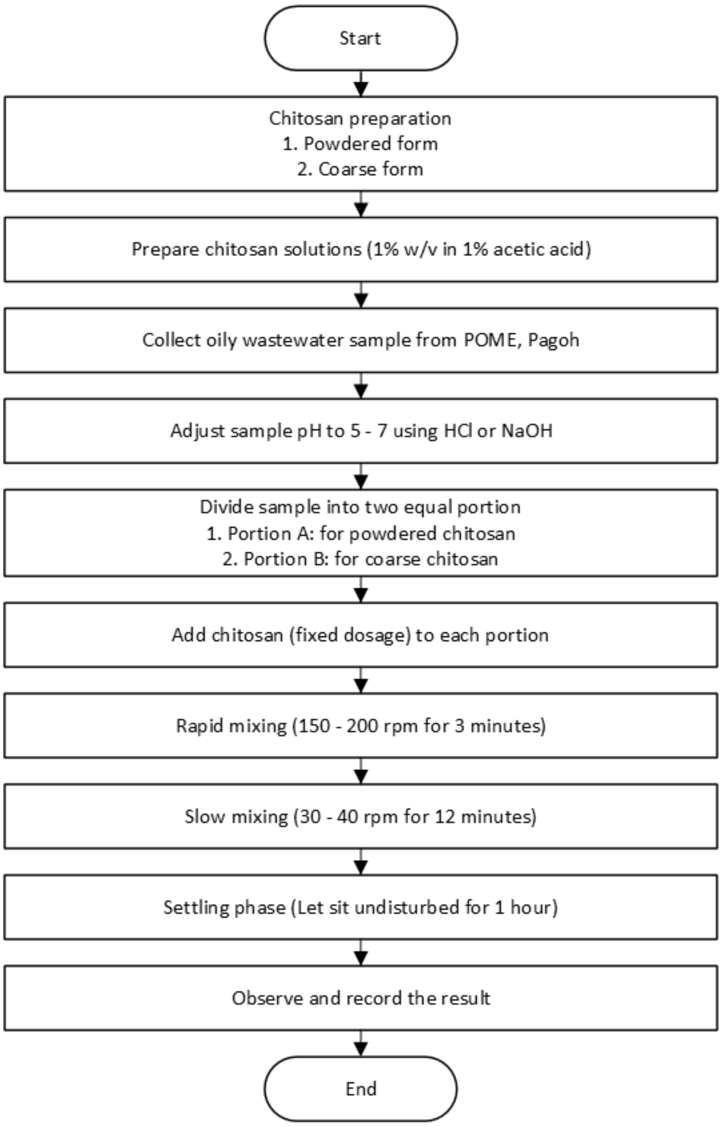

Figure 1.3: The flowchart of coagulation-flocculation experiment

4.0 Discussion of analysis and findings

4.1 The Characterization of the Coagulant Produced

The coagulants used in this study consisted of chitosan in powder (pH 9.83) and coarse (pH 9.77) forms, extracted from shrimp waste. As shown in Table 1.2, both forms exhibited 57.46% moisture content, 91.46% yield, 6.67% ash content, and a degree of deacetylation (DD) of 59.24%.

Table 1.2: The characterization of the coagulant produced

Coagulant type	Moisture content, %	Percentage Yield, %	Ash Content, %	Degree of Deacetylation, %
Powder	57.46	91.46	6.67	59.24
Coarse	57.46	91.46	6.67	59.24

The measured moisture content of 57.46% indicates that the chitosan samples retained a moderate amount of water post-drying. While slightly lower than the recommended upper limit of 75.9%, this level is still within acceptable boundaries for storage and application. Moisture content is critical in maintaining shelf life, microbial stability, and overall coagulant performance. Excessive moisture may lead to microbial contamination, whereas too little can result in brittle and less-reactive material. This balance ensures that chitosan remains a reliable and stable coagulant, especially for decentralized or small-scale operations where storage conditions may vary.

Using chitosan in two distinct forms (powder and coarse) allows for a direct assessment of how particle size influences coagulation efficiency. Finer particles typically provide greater surface area for interaction with suspended particles and emulsified oils in wastewater, which can accelerate floc formation. However, the coarse form may exhibit advantages in settling behavior and ease of separation, especially when the effluent contains heavier contaminants. The comparison in this study helps identify which physical form is more effective under a fixed dosage.

The degree of deacetylation is a key structural indicator affecting the charge density and solubility of chitosan (Hosney, Ullah, & Barčauskaitė, 2022). The recorded DD of 59.24% places the samples in the low deacetylation range (55–70%), rendering the chitosan practically insoluble in water. While higher DD (>70%) chitosan may dissolve and disperse more easily, lower DD enhances solid-state coagulation and facilitates easier floc separation, which is beneficial in treating oil emulsions like POME. Importantly, insoluble chitosan minimizes residuals in the treated water, making it environmentally safer than soluble polymer-based flocculants.

The high yield (91.46%) suggests an efficient extraction process, transforming shrimp waste into a high-value product. The ash content (6.67%) falls within acceptable limits (<10%), indicating a successful demineralization step and minimal inorganic residue in the final product. Lower ash content improves the purity and efficiency of chitosan during coagulation, as high mineral content may hinder charge interaction with pollutants.

The choice of coagulant in wastewater treatment affects not only pollutant removal efficiency but also environmental impact, cost, and sustainability. Chemical coagulants like alum and ferric chloride are effective and widely used but raise concerns due to metal toxicity, sludge production, and eutrophication. In contrast, bio-based coagulants such as chitosan from shrimp waste offer eco-friendly, safer alternatives. The Table 1.3 below compares chemical and bio-based coagulants across key criteria to highlight their respective advantages and limitations.

Table 1.3: Comparison with conventional chemical coagulants

Property / Parameter	Chitosan (Bio-based)	Ferric Chloride / Aluminium Sulphate (Chemical)
Source	Shrimp waste (natural)	Inorganic chemicals (mined or synthesized)
Toxicity	Non-toxic, biodegradable	Can leave residual heavy metal (Fe, Al)
Residual Sludge	Biodegradable, less volume	Toxic, large volume, need special disposal
Coagulant pH Range	Effective at near-neutral pH	Requires pH adjustment (usually acidic)
Ash Content	~ 6.67%	Not applicable, but may introduce mineral load
Moisture Content	~ 57.46%, moderate stability	Typically dry powders, chemically stable
Degree of Deacetylation	59.24%, insoluble, stable	Not applicable
Floc Quality	Strong, biodegradable flocs	Dense flocs, but may contain toxic residue
Cost & Availability	Low-cost if waste is available	Higher cost, supply chain dependent
Environmental Impact	Low (natural origin)	High (Eutrophication risk, metal toxicity)

4.2 Turbidity Value in Oily Waste Emulsion after Treatment

The turbidity of treated water, which is a measure of its cloudiness, is assessed using a turbidity meter, with relevance to determining coagulant effectiveness. After allowing an oily waste emulsion to remain in contact with chitosan for 15 minutes, the mixture is subsequently separated into wastewater and chitosan components. To evaluate turbidity, small samples of both types of wastewaters, treated with coarse and powder chitosan, are subjected to turbidity measurements using a turbidity meter. The acceptable standard for treated water typically lies below 5 NTU, with a preference for values below 1 NTU and an ideal target below 0.1 NTU (WATER QUALITY AND HEALTH-REVIEW OF TURBIDITY: Information for Regulators and Water Suppliers, n.d.). However, following the coagulation process, the turbidity values for the powder and coarse chitosan-treated wastewater are measured at 18.72 NTU and 21.80 NTU, respectively, as shown in Figure 1.4 indicating a significant decrease in turbidity levels post-coagulation treatment.

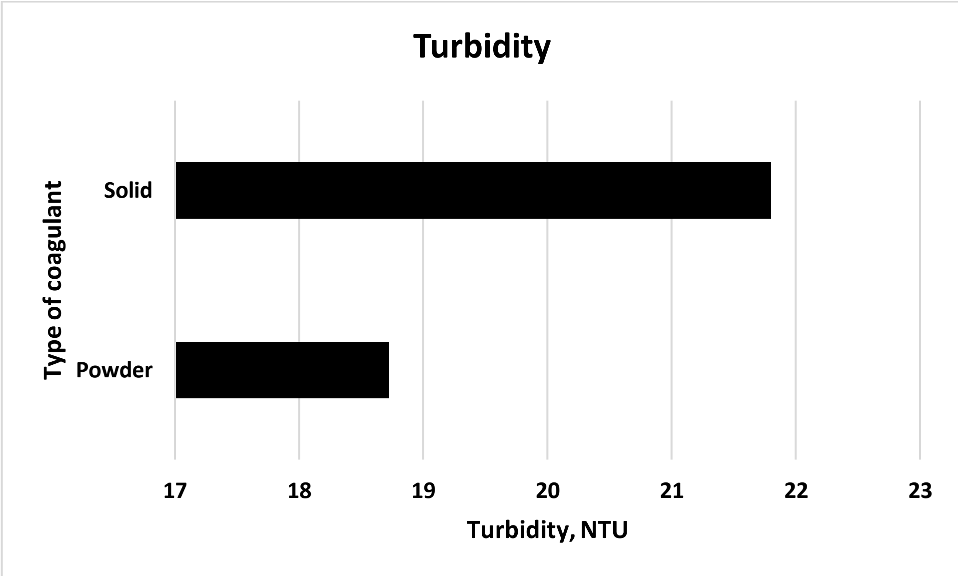

Figure 1.4: The turbidity value in oily waste emulsion after treatment

4.3 pH Value of Oily Waste Emulsion after Treatment

According to the National Water Quality Standards for Malaysia, wastewater discharge regulations encompass a variety of pH classes. Generally, adherence to universal standards requires pH levels to fall within the range of 6 to 10, although certain applications or locales may permit deviations beyond these bounds. The pH meter serves as the instrument for determining the pH levels of both types of wastewaters. Following the coagulation process, the pH values for the powder and coarse chitosan-treated wastewaters are recorded at 9.83 and 9.77, respectively as shown in Figure 1.5. The observed slight increase in pH can be attributed to the alkaline nature of chitosan. Nevertheless, these pH levels remain within permissible limits for wastewater discharge or release.

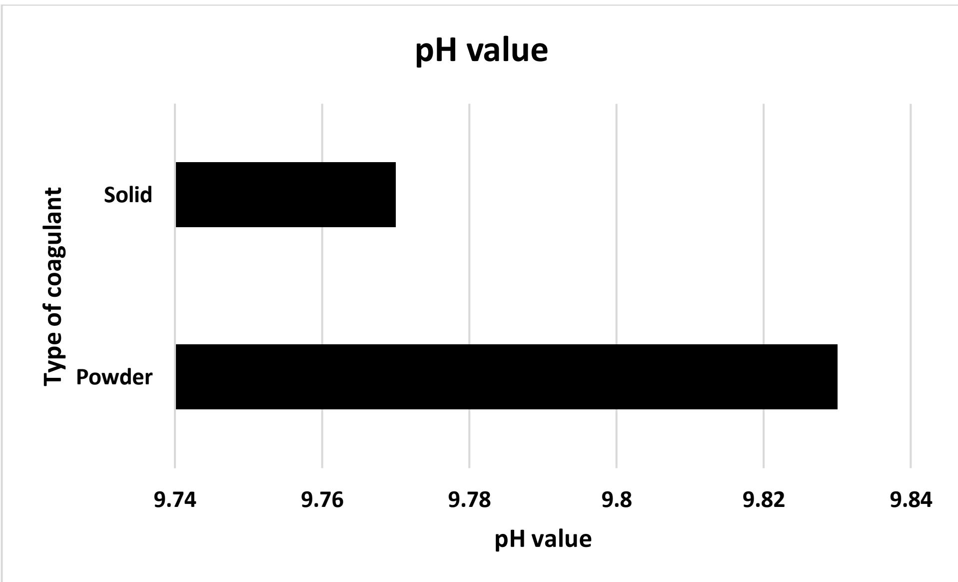

Figure 1.5: The pH value of oily waste emulsion after treatment

4.4 The Percentage of Coagulation Activity

The findings in Figure 1.6 indicate that powdered chitosan demonstrates slightly higher coagulation effectiveness (91.79%) compared to coarse chitosan (90.44%). While the difference is minor at the laboratory scale, this distinction holds practical implications in industrial settings. Powdered chitosan, with its finer particle size and larger surface area, allows for better dispersion and more effective interaction with suspended particles in wastewater. This enhances floc formation and sedimentation, potentially improving treatment speed and reducing retention time in industrial-scale reactors. Its consistent texture may also allow for more controlled dosing and uniform mixing

In contrast, coarse chitosan, although nearly as effective, may not distribute as evenly throughout the wastewater and could require longer reaction times or mechanical assistance to achieve comparable flocculation. However, coarse chitosan could be easier and less costly to produce, especially when minimal grinding or processing equipment is available. This trade-off between ease of preparation and performance must be considered when selecting the appropriate form for large-scale use

Despite these benefits, several limitations could affect the broader application of chitosan, especially in large-scale operations. First, the production of chitosan from shrimp waste requires consistent access to raw materials, as well as controlled processing conditions (e.g., deproteinization, demineralization, and deacetylation). Scaling up this process might demand investment in equipment and adherence to quality control to ensure consistent degrees of deacetylation and purity. Additionally, powdered chitosan may present challenges in storage and handling due to its hygroscopic nature, potentially affecting shelf life and coagulation efficiency if not properly managed

Furthermore, compared to chemical coagulants, bio-coagulants like chitosan generally have a shorter shelf life and may be sensitive to pH or temperature variations, which can affect their performance in different industrial wastewater types. Despite these challenges, the environmental benefits such as reduced sludge volume (20–30% less than alum), lower toxicity, and biodegradability, position chitosan as a promising sustainable alternative, especially where regulatory or environmental pressures demand greener treatment solutions

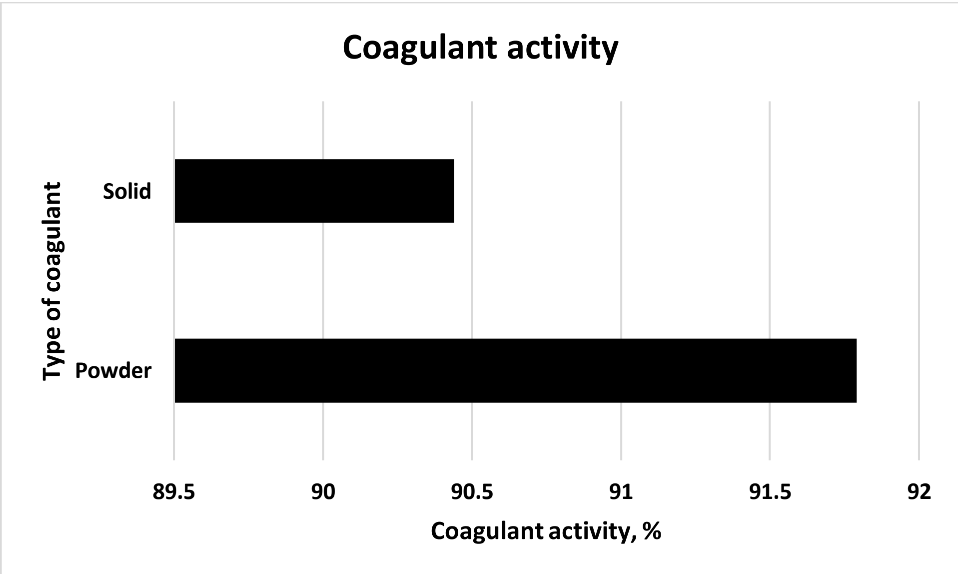

Figure 1.6: The percentage of coagulation activity

5.0 Conclusion and Future Research

Consequently, chitosan has no negative environmental effects and presents a promising solution for industrial wastewater treatment via coagulation and flocculation. The chitosan produced under the specified extraction conditions exhibited a satisfactory degree of deacetylation (59.24%) and shared qualitative properties with commercially available chitosan. A comparative analysis revealed that powdered chitosan was more effective than coarse chitosan, achieving a coagulation efficiency of 91.79%. Thus, the project's objectives were successfully met

To further enhance the production and application of chitosan in wastewater treatment, several recommendations can be made. First, optimizing the extraction process such as by refining demineralization and deacetylation steps could improve yield and reduce operational costs. Using lower concentrations of reagents or exploring enzyme-assisted extraction methods may help minimize chemical consumption and environmental impact. Process automation and energy-efficient drying techniques (e.g., freeze-drying instead of high-temperature drying) could also enhance scalability and product quality

For future research, several avenues should be explored to broaden the applicability of bio-based coagulants. These include testing the performance of chitosan in various types of industrial wastewater such as textile, tannery, or pharmaceutical effluents, where pollutant compositions vary significantly. Additionally, sourcing chitosan from alternative bio-wastes, such as crab shells, insect biomass, or fungi, may offer cost-effective and regionally accessible options. It is also recommended to investigate the potential for recovering and reusing chitosan after treatment to align with circular economy principles. Incorporating modified or composite forms of chitosan such as cross-linked or magnetized variants could further improve removal efficiency and ease of separation

Overall, the development of low-cost, sustainable, and high-performance chitosan-based coagulants could significantly advance eco-friendly wastewater management technologies.

Acknowledgements

The journal committee would like to thank all the authors for their manuscript contributions.

Author Contributions

Abdullahyi S.: Conceptualization, Methodology, Writing- Original Draft Preparation and Editing; **Kok Seng L.**: Data Curation, Validation, Supervision**; Alva S.**: Validation, and Writing-Reviewing.

Conflicts of Interest

The manuscript has not been published elsewhere and is not being considered by other journals. All authors have approved the review, agree with its Submission, and declare no conflict of interest in the manuscript.

6.0 References

Adetunji, A. I., & Olaniran, A. O. (2021). Treatment of industrial oily wastewater by advanced technologies: a review. In *Applied Water Science* (Vol. 11, Issue 6). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s13201-021-01430-4

Aguilera Flores, M. M., Valdivia Cabral, G. I., Medellín Castillo, N. A., Ávila Vázquez, V., Sánchez Mata, O., & García Torres, J. (2023). Study on the Effectiveness of Two Biopolymer Coagulants on Turbidity and Chemical Oxygen Demand Removal in Urban Wastewater. *Polymers*, *15*(1). https://doi.org/10.3390/polym15010037

Akinnawo, S. O. (2023). Eutrophication: Causes, consequences, physical, chemical and biological techniques for mitigation strategies. In *Environmental Challenges* (Vol. 12). Elsevier B.V. https://doi.org/10.1016/j.envc.2023.100733

Arturi, T. S., Seijas, C. J., & Bianchi, G. L. (2019). A comparative study on the treatment of gelatin production plant wastewater using electrocoagulation and chemical coagulation. *Heliyon*, *5*(5). https://doi.org/10.1016/j.heliyon.2019.e01738

Iwuozor, K. O. (2019). Prospects and Challenges of Using Coagulation-Flocculation Method in the Treatment of Effluents. *Advanced Journal of Chemistry, Section A*, *2*(2), 105–127. https://doi.org/10.29088/SAMI/AJCA.2019.2.105127

Kurniawan, S. B., Abdullah, S. R. S., Imron, M. F., Said, N. S. M., Ismail, N. 'Izzati, Hasan, H. A., Othman, A. R., & Purwanti, I. F. (2020). Challenges and opportunities of biocoagulant/bioflocculant application for drinking water and wastewater treatment and its potential for sludge recovery.

In *International Journal of Environmental Research and Public Health* (Vol. 17, Issue 24, pp. 1–33). MDPI AG. https://doi.org/10.3390/ijerph17249312

Masron, Z., Ahmad, A., & Farihah Adnan, N. (2023). *Palm Oil Mill Effluent (POME) Pretreatment Using Tapioca Starch as A Coagulant* (Vol. 4, Issue 1). https://journal.pktm.com.my

Mohamed Noor, M. H., & Ngadi, N. (2024). Ecotoxicological risk assessment on coagulation-flocculation in water/wastewater treatment: a systematic review. *Environmental Science and Pollution Research*, *31*(40), 52631-52657.

Raissi, S. (2023). *Optimization of sunlight photo-catalytic treatment coupled to a coagulation-occulation process*. https://doi.org/10.21203/rs.3.rs-1959503/v2

Teh, C. Y., Wu, T. Y., & Juan, J. C. (2014). Potential use of rice starch in coagulation-flocculation process of agro-industrial wastewater: Treatment performance and flocs characterization. *Ecological Engineering*, *71*, 509–519. https://doi.org/10.1016/j.ecoleng.2014.07.005

WATER QUALITY AND HEALTH-REVIEW OF TURBIDITY: Information for regulators and water suppliers. (n.d.).

Yu, L., Han, M., & He, F. (2017). A review of treating oily wastewater. In *Arabian Journal of Chemistry* (Vol. 10, pp. S1913–S1922). Elsevier B.V. https://doi.org/10.1016/j.arabjc.2013.07.020

Zaki, N., Hadoudi, N., Charki, A., Bensitel, N., Ouarghi, H. El, Amhamdi, H., & Ahari, M. (2023). Advancements in the chemical treatment of potable water and industrial wastewater using the coagulation–flocculation process. In *Separation Science and Technology (Philadelphia)* (Vol. 58, Issues 15–16, pp. 2619–2630). Taylor and Francis Ltd. https://doi.org/10.1080/01496395.2023.2219381