

Effectiveness Of Date Dry Seed as a Natural Coagulant in Wastewater Treatment Process

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DOI: <https://doi.org/10.30880/ijscet.2024.15.03.015>

Article Info

Received: 18 April 2024
Accepted: 11 December 2024
Available online: 22 December 2024

Keywords

Natural coagulant, wastewater treatment, date seed, textile wastewater

Abstract

Organic and inorganic compounds, heavy metals, and insoluble substances contaminate industrial effluents. The environmental hurdles for the textile industry stem from the diversity in colours and chemical elements present in its waste output. The coagulation-flocculation method is highly regarded for its capability to remove biodegradable substances, suspended solids, turbidity, and colouration from industrial wastewater. However, the application of chemical coagulants, despite their effectiveness, poses significant drawbacks due to their high cost and the generation of sizable quantities of non-biodegradable waste and metallic traces in the water, potentially leading to contamination and health hazards. An alternative approach gaining attention involves the use of plant-based, natural coagulants. These are not only non-toxic and biodegradable but also environmentally sustainable. This study aims to evaluate the potential of date seed extract as a natural coagulant in treating wastewater from the textile industry. The extraction of the coagulant was performed using distilled water and NaCl. Parameters such as Chemical Oxygen Demand (COD), turbidity, ammonia nitrogen, and pH levels were measured to assess the purification efficacy of the date seed on the textile wastewater. Experiment results revealed that the date seeds have remarkable coagulation properties. The optimal dosage of date seed to remove COD, ammonium nitrogen, and turbidity was determined to be 56.19%, 43.33%, and 83.96%, respectively. The concentration of 2.0M NaCl is optimal for removing COD and ammonia nitrogen, whereas the concentration of 1.0M NaCl is optimal for eliminating turbidity. The research findings demonstrated the potential benefits of using date seed as a natural coagulant in treating textile industrial effluent.

1. Introduction

Industrial wastewater is contaminated with organic and inorganic substances, heavy metals, and materials that do not dissolve. The nature of these pollutants differs across industries, with many types of present. Wastewater

is produced by various industries, including the refining of minerals, the production of paper, the shaping of iron and metal, and the brewing of beer. In numerous situations, it is necessary to treat industrial wastewater with cost-effective methods [1]. Due to numerous dyes and chemical additives, the textile industry faces environmental difficulties ceasing its waste discharge. The primary pollutants in textile wastewater stem from dyeing processes, contributing to high chemical oxygen demand, elevated temperatures, and abundant suspended solids and colour. As a result, textile waste has a complicated chemical makeup [2].

Water treatment separates hazardous substances from water to make it suitable for human and household usage. Coagulation, flocculation, sedimentation, filtration, and disinfection are all integral steps in the treatment process [3]. The method of coagulation-flocculation is frequently applied in the treatment of water and wastewater to eliminate suspended solids, organic substances, turbidity, and discolouration. Ordinarily, coagulation is followed by flocculation, which aids in clustering particles to enhance their removal through sedimentation or filtration [4]. The conventional coagulation process typically employs divalently charged positively chemical substances, including aluminium sulphate and poly-aluminium chloride [5].

Several disadvantages are associated with using chemical coagulants in wastewater treatment procedures. First, chemical coagulants can be costly, resulting in increased production costs in effluent treatment [6]. This can be especially burdensome for industries and regions with limited effluent treatment funding. In addition, chemical coagulants can have adverse environmental effects. Chemical purification processes, such as coagulation, can generate substantial quantities of non-biodegradable sediment and metallic residues in treated water, which can be sources of disease and environmental contamination [7]. In addition, chemical coagulants may harm human health and the environment [8]. The highly toxic chemical precipitates left behind by chemical coagulants can be hazardous to human health and the environment. Ishak Hasnan, who leads the Malaysian Water Engineers Action Committee (MyWAC), has stated that chemicals used in water treatment represent approximately 20 to 30 per cent of the total costs involved in the treatment process. Consequently, any escalation in the pricing of these chemicals directly translates into a proportional rise in the costs incurred for water treatment. These problems can lead to financial difficulties, poor water quality, and potential health risks [9].

Concerns have been raised regarding chemical coagulants' environmental, health, and long-term implications for water purification. This has increased interest in exploring natural coagulants derived from plant or microbial sources as potential substitutes. These natural alternatives could provide solutions to the issues mentioned above. Opting for natural coagulants over chemical ones reduces the amount of waste and health hazards associated with residual chemicals, thereby enhancing the sustainability of water treatment processes. According to Owodunni and Ismail (2021), natural coagulants require lower concentrations and generate less sediment [10]. This reduces the cost of coagulants and sediment. The need for a lower dosage stems from the efficiency of natural coagulants. These coagulants excel in charge neutralisation and polymer bridging, which is essential for eliminating contaminants. Natural organic coagulants have many intriguing advantages over artificial chemical coagulants [11].

Date seeds are recommended as natural coagulants for water purification in Malaysia because they are popular and widely available fruit throughout the nation, with various types and varieties sold in local markets, supermarkets, and fruit stands. Dates, or *Phoenix dactylifera* L., is a monocotyledonous woody perennial fruit tree in the family *Arecaceae* [12]. Due to its nutritional, economic, and medicinal benefits, its fruits are consumed by millions of people around the globe [13]. Date seed can be utilised in effluent treatment as a natural coagulant. A study found that using date palm seed as a coagulant to remove turbidity from effluent had a performance of 62.54 per cent [14]. Another study derived a bio-coagulant from date pits and found that at a pH of 13 and a crude extract dose of 1ml/L, it had an 86% removal efficacy. The study also suggested that, as waste materials, date pits are appropriate for coagulation-flocculation treatment of muddy water [15]. It is essential to note that the efficacy of date seed as a coagulant can vary depending on the specific conditions of the effluent being treated.

Other studies use the extract as a coagulant. The study from Zedan *et al.* (2022) used walnut seeds as a natural coagulant with NaCl as a solvent to remove turbidity from synthetic turbid wastewater. The best dosage for walnut seed extract is three ml/L, achieving maximum effectiveness in reducing turbidity at a pH exceeding 7 [16]. Another study by Lek *et al.* (2018) removed turbidity, TSS, and COD from palm oil mill effluent (POME) using chickpea powder. The study findings reduced effluent turbidity by 86%, TSS by 87%, and COD by 56%, respectively. Moreover, a Fourier Transform Infrared (FTIR) study of chickpea powder showed the existence of OH, CH, NH, CC, CO, and CN groups, which help with the mechanism for bridging flocculation throughout the coagulation technique [17].

Various contaminants negatively impact the efficiency of natural coagulants. Seed powder contains substances that can act as coagulants, but the high level of organic material in plant tissues increases the organic load of the water being treated. Furthermore, components like oils and lipids can impede their coagulating abilities. Research has focused on extracting active coagulation agents to improve the reduction of turbidity and the effectiveness of coagulation. However, the success of these bio-coagulants in treating water and effluents hinges on the methods used for their extraction [10]. Distilled water is the most familiar and inexpensive extraction-based solvent. Nevertheless, it is not as efficient as a salt mixture, such as sodium chloride (NaCl) and

sodium hydroxide (NaOH), in disrupting the protein-protein bonds within coagulant sources, which show good coagulation efficiency through the salting-out effect and keep getting in the way of hydrophobic substances in the extracts [18].

This research seeks to use a natural coagulant obtained from date seeds as a substitute for a chemical coagulant. In this investigation, the study looks at the efficacy of date seeds as organically produced coagulants in water treatment processes. Based on the available literature, more research needs to be conducted on employing the chosen seedlings during coagulation in wastewater treatment. Even though studies are using selected seeds as natural coagulants, there needs to be more studies on how different concentrations of solvent extraction can influence the efficacy of date seed as an organic coagulant in water treatment processes, especially in textile wastewater.

2. Methodology of the Study

2.1 Preparation Of Date Seed Powder

The cleaning of the date seed was performed with distilled water, and then it was subjected to a six-hour drying period at 65 °C to remove all moisture. Subsequently, the seeds were ground into a fine powder using an electric blender, and the resulting product was sifted to guarantee uniform particle size, as illustrated in Figure 1.



Fig. 1 Date seed preparation (a) Date seed; (b) Date seed powder

100 mL of distilled water or sodium chloride (NaCl) was mixed with 2 g of date seed powder to generate a coagulant solution. A magnetic stirrer was used to mix the solutions for a total of 45 minutes. and filtered using filter paper. Date seed powder was dissolved in distilled water and varied concentrations of NaCl to create a coagulant solution. 0.5M, 1M, 1.5M, and 2.0M of NaCl were used in this experiment.

2.2 Preparation Of Textile Wastewater

The wastewater sample examined in this research was sourced from an industrial region in Tongkang Pechah, Batu Pahat, Johor. The textile effluent produced by the industrial activities in the area was the origin of this wastewater sample. The effluent used in the research was analysed to identify its initial characteristics. It is revealed that the wastewater's initial turbidity was 88 NTU. Meanwhile, initial COD and ammonia levels were 1248 mg/L and 22.88 mg/L, respectively.

2.3 Jar Test

The ASTM D2035 standard was crucial in the study, as it was utilised to perform the Coagulation-Flocculation Jar Test on wastewater samples. The procedures for carrying out jar tests to assess the efficiency of coagulation and flocculation processes in treating water and wastewater have been thoroughly outlined in ASTM D2035. This includes an experimental approach, depicted in Figure 2, involving six of 1L beakers, each contained of 0.5L wastewaters. Before beginning the stirring process, critical parameters such as initial pH, turbidity, and COD were measured from the wastewater samples. The experimental setup was completed with the apparatus being installed, where the samples were stirred initially at a high speed of 100 rpm for two minutes, followed by a reduction in speed to 25 rpm for 20 minutes. Subsequently, the mixture was left undisturbed to settle for 30 minutes [14].



Fig. 2 Jar test process

2.4 Data Collection

Several parameters will be investigated in this study. Five consists of characterisation parameters from the Water Quality Index (WQI) that will be taken once the water is spent from the mentioned wastewater sample. Table 1 below shows the parameter data that is involved in this study.

Table 1 Methods and parameters of characterisation

Parameters	Method
Turbidity	Extech TB400 turbidity meter
Chemical Oxygen Demand (COD)	Reactor Digestion Method (Hach Method 8000)
pH	HQ440D Laboratory Dual Input, Multi-Parameter Meter
Ammonia Nitrogen	Nessler Method (Hach Method 8038)

2.4.1 Chemical Oxygen Demand (COD)

Analysing the COD removal data involves assessing the efficiency of natural coagulants in lowering turbidity in wastewater and understanding how COD connects with various environmental variables. Equation (1) was utilised to evaluate the date seed coagulant's effectiveness in reducing the wastewater's COD.

$$\text{COD Reduction (\%)} = \frac{COD_1 - COD_2}{COD_1} \times 100\% \quad (1)$$

Where:

COD_1 = Initial COD (mg/l)

COD_2 = Final COD (mg/l)

2.4.2 Turbidity Removal

Examining turbidity removal data means figuring out how well natural coagulants reduce turbidity in effluent and how turbidity relates to different environmental factors. Equation (2) was used to determine the effectiveness of the date seed coagulant in eliminating the turbidity of the water.

$$\text{Turbidity Reduction (\%)} = \frac{T_1 - T_2}{T_1} \times 100\% \quad (2)$$

Where:

T_1 = Initial turbidity (NTU)

T_2 = Final turbidity (NTU)

2.4.3 Ammonia Nitrogen Removal

Analysing Ammonia Nitrogen removal data involves determining how well natural coagulants reduce turbidity in effluent and how turbidity relates to various environmental factors. By analysing the data, it is possible to identify the most influential factors affecting ammonia nitrogen removal, satisfy regulatory requirements, and safeguard the environment from the harmful effects of ammonia nitrogen pollution. This formula is a straightforward and effective optimisation tool for wastewater treatment procedures. Equation (3) was utilised to ascertain the efficacy of the date seed coagulant in reducing the Ammonia Nitrogen content of the water.

$$\text{Ammonia Reduction (\%)} = \frac{AN_1 - AN_2}{AN_1} \times 100\% \quad (3)$$

Where:

AN_1 = Initial Ammonia (mg/l)

AN_2 = Final Ammonia (mg/l)

3. Results and Discussion

3.1 The Effectiveness of Date Seed Coagulant in Lowering COD Levels

Reducing the chemical oxygen demand (COD) is a crucial aspect of wastewater treatment because it indicates the concentration of organic pollutants in the water. Figure 3 depicts a line graph of five solutions with differing coagulant concentrations. Except for the solvent 1.0M NaCl concentration, most graphs exhibit a rising trend with a peak performance reduction at 1.0 g/L dosage. The removal efficiency initially increased with the preponderance of the concentration coagulant until it reached a dose of 1.0 g/L, which decreased.

Aal-Hamad (2023) mentioned date seed powder can remove pollutants from wastewater because it is rich in natural polyphenols that capture dissolved organic matter and mineral ions. As a result of the aggregation and congestion of coagulants, the removal efficiency decreases and becomes unbalanced when COD is eliminated [19]. Abujazar *et al.* (2022) have suggested that by surrounding the outer layer of the natural coagulant, an excessive concentration of the coagulant decreases the available adsorption sites for particle bridging, resulting in a saturation or equilibrium point at a dosage of 1.0 g/L [20].

High chloride concentrations in NaCl solutions can compromise measurement accuracy, particularly in Chemical Oxygen Demand (COD) tests that depend on oxidation. In many standard COD procedures, chloride ions can react with oxidizing agents such as potassium dichromate, leading to inflated COD results due to side reactions with chlorine. This interference poses challenges in accurately determining the actual organic load in wastewater. To mitigate this issue and enhance the reliability of COD readings, some testing protocols utilize chloride-masking agents or incorporate correction factors.

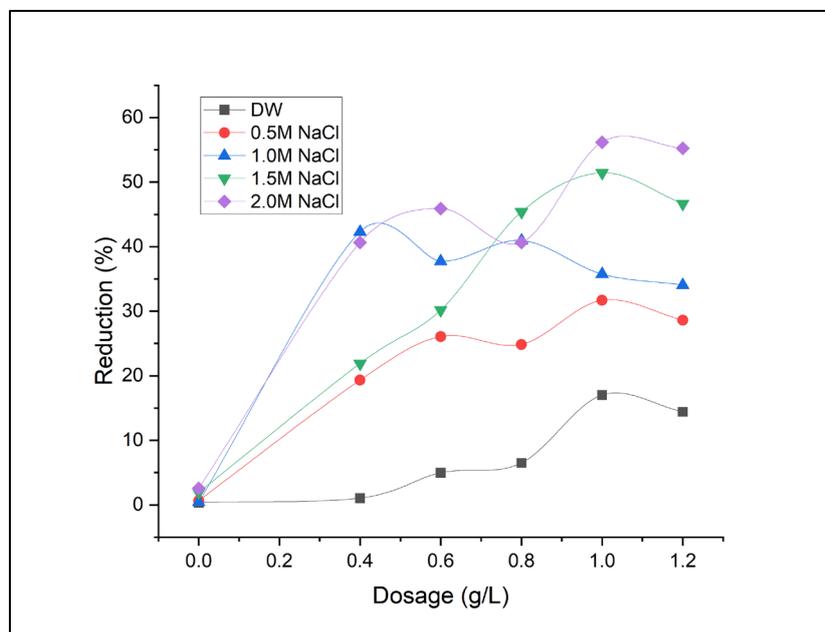


Fig. 3 Percentage of COD reduction vs Coagulant dosage

3.2 The Effectiveness of Date Seed Coagulant in Decreasing Water Turbidity

A line chart illustrating six distinct solutions with varied coagulant doses is shown in Figure 4. Increases in NaCl concentration resulted in more significant turbidity removal for all date seed coagulant solutions. All date seed coagulant solutions with NaCl as solvent show the optimum dosage for turbidity removal at 0.4 g/L. Meanwhile, the date coagulant solution with distilled water only has a peak dosage of 1.0 g/L with turbidity elimination of 17.39%. The highest turbidity removal was 83.96% with a dosage of 0.4 g/L in the concentration of 1.0M NaCl. This effective turbidity reduction is attributable to the exceptional adsorption of pulverised date seeds in suspended solids [21].

The presence of positively charged amino groups in date seeds enhances the ability to bridge colloids and particulates in the water undergoing treatment, subsequently improving the flocculation process [22]. However, when the dosage of NaCl in the date seed coagulant reaches 0.6 g/L, there is a cessation in the increase of turbidity removal percentages, which then decline gradually. Additionally, the substantial molecular weight of the date powder, when not in an aqueous solution and present in wastewater, means that using an excessive amount of date seed could significantly raise the powder concentration. This increase could reduce the efficiency of the flocculation process [23].

Aside from this, the presence of NaCl can enhance coagulation in various ways. According to Zhao *et al.* (2018), NaCl is an electrolyte ion capable of triggering coagulation by causing colloidal particles to aggregate and settle due to the salting-out effect. In addition, the existence of NaCl improves the ionic power of the mixture, which decreases the electrostatic repulsion between particles and promotes their aggregation [24]. Therefore, NaCl extracts from the active coagulating agents reduce chemical content and help enhance coagulation efficiency with the charge neutralisation mechanism.

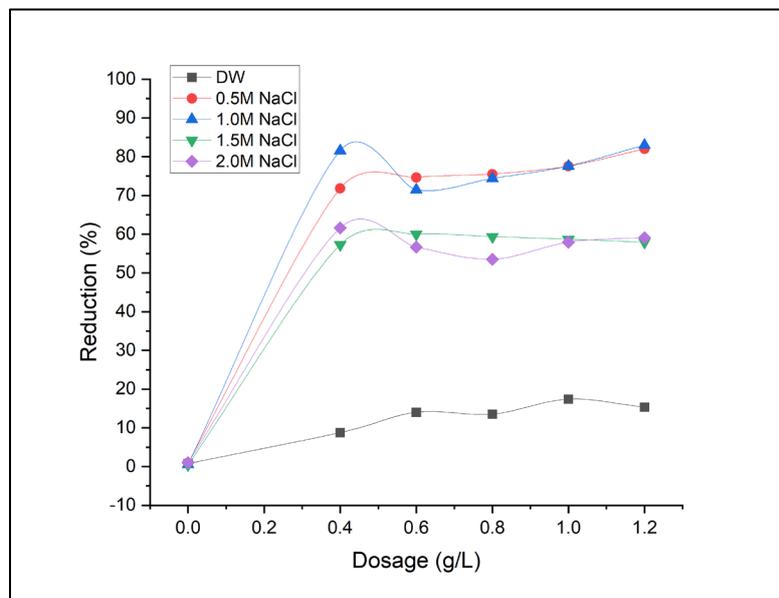


Fig. 4 Percentage of turbidity reduction vs Coagulant dosage

3.3 The Effectiveness of Date Seed Coagulant in Altering pH Levels

As shown in Figure 5, the most drastic change in pH was the concentration of a coagulant solution of 1.5 M NaCl, which was from 6.98 to 7.36. However, this drastic change in pH still puts the sample water in the neutral range. The control sample has a neutral pH range from 6.98 to 7.06, and the blank sample is used. The date seed coagulant solution of NaCl concentration shows a slight increase in pH except for 2.0M NaCl concentration and distilled water. In conclusion, at varying dosages, there were no significant changes in pH for the water sample treated with date seed as a coagulant. However, all other parameters of the water sample decreased significantly after treatment.

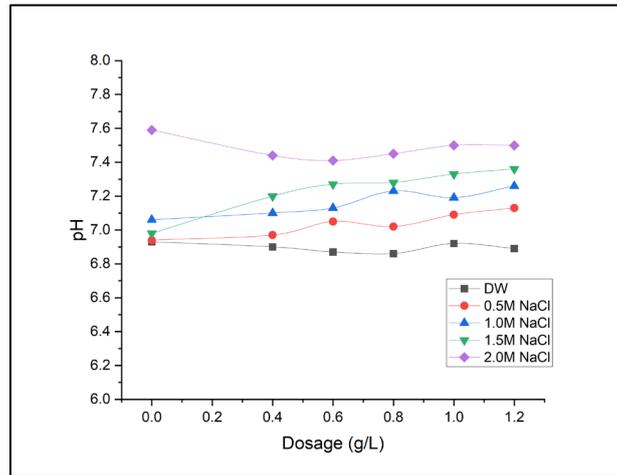


Fig. 5 pH vs Coagulant dosage

3.4 The Effectiveness of Date Seed Coagulant in Lowering Ammonia Nitrogen Levels

Figure 6 demonstrates the relationship between the percentage of ammonia nitrogen reduction and the dosage of date seed coagulant. When the dosage of date seed coagulant is increased, the graph depicts an ascending and then descending trend in the percentage of ammonia nitrogen reduction. The highest ammonia nitrogen reduction was at 20 ml date seed coagulant dosage of 2.0M NaCl at removal of 43.33%. For 2.0M NaCl and 1.0M NaCl, the decreasing trends begin at 25 ml coagulant dosage, whereas for 1.5M NaCl and distilled water, the decreasing trends begin at 0.8 g/L coagulant dosage. Aside from this, only 0.5M NaCl has a decreasing point at 0.6 g/L coagulant dosage but a minor increase at 25 ml coagulant dosage.

Abu Amr *et al.* (2022) mentioned that the ability of date seed to reduce ammonia may result from the activity of electric double layers generated by carboxylic, amino groups, and phenolic [25]. The wastewater contains solid particles that agglomerate, grow, and then flow into the base of the support. The increased efficacy of date seed powder in treating and removing ammonia nitrogen is due to its molecular structure, which contains coagulants [19]. Additionally, there may be a decrease in ammonia nitrogen reduction at specific dosages because there are too many coagulants. This makes it harder for colloidal particles to stick to the surface of the natural coagulant, which causes a reduction in ammonia nitrogen.

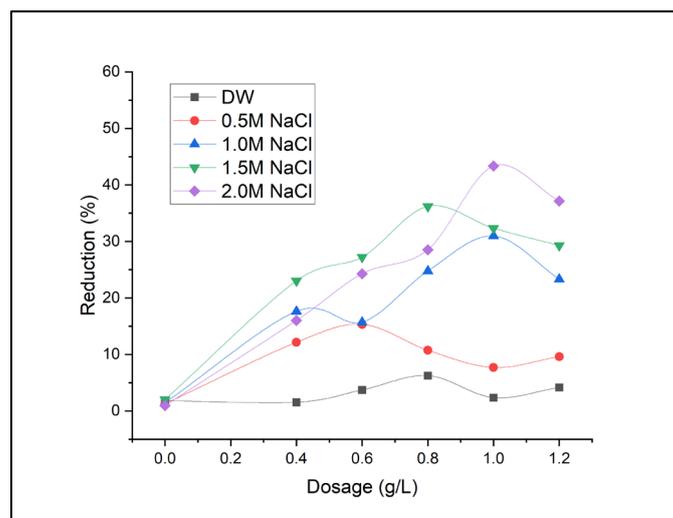


Fig. 6 Percentage of ammonia nitrogen reduction vs Coagulant dosage

3.5 Comparison of Outcomes from This Study with Previous Research Findings

Table 2 provides a synthesised comparison between the results of the current investigation and those found in the literature. It looks at how various natural coagulants impact the reduction of turbidity and chemical oxygen demand (COD) in wastewater, highlighting that date seeds have been extensively studied so far. This study used date seed coagulant with varying concentrations of NaCl solvent, whereas another study only used a single concentration. Date seed was marginally more effective than pigeon pea and *Carica papaya* at reducing turbidity,

except in carwash, kaolin, and raw river. Note that Carica papaya and pigeon pea performed better but were tested under different wastewater conditions. In a separate study on date seed, a different type of wastewater was used, which produced superior results. The preceding result demonstrated that date seeds could serve as a replacement for chemical coagulants. It also demonstrated that readily available date seedlings have additional benefits.

Table 2 Comparison of outcomes derived from current literature

Sort of wastewater	Natural coagulant	Initial Reading	Turbidity removal (%)	COD removal (%)	Ref.
Iron and steel industrial wastewater	Date seed	COD: 840 mg/L	-	96.50%	[25]
Carwash wastewater	Carica Papaya seed	Turbidity: 170 NTU COD: 220 mg/L	97.00%	35.91%	[26]
Kaolin synthetic wastewater	Pigeon Pea (<i>Cajanus cajan</i>)	Turbidity: 250 NTU	97.80%	-	[14]
Raw river water sample	Carica Papaya seed	Turbidity: 35 NTU	89.14%	-	[27]
Synthetic turbid water	Date seed	Turbidity: 120 NTU	71.33%	-	[28]
Textile industrial wastewater	Date seed	Turbidity: 88 NTU COD: 1248 mg/L	83.96%	56.19%	This study

4. Conclusion

This research highlights how fruit seed remains abundant and renewable and can produce natural coagulants through distilled water or safe inorganic salts. Extracts from date seed powder using NaCl solution have shown their efficacy as organic natural coagulants in reducing chemical oxygen demand (COD), turbidity, and ammonia nitrogen levels in textile industry wastewater. This experiment has showcased the significant coagulating capabilities of date seeds. The optimal dosage of date seed to remove COD, ammonia nitrogen, and turbidity was determined to be 56.19%, 43.33%, and 83.96%, respectively. The 2.0M NaCl concentration is optimal for removing COD and ammonia nitrogen, while the 1.0M NaCl concentration is optimal for removing turbidity. Adding date seed powder, which is of organic composition, to wastewater from industrial factories did not change pH levels. The coagulation process utilising date seed extract in combination with NaCl as a solvent shows potential for treating textile wastewater by effectively reducing suspended solids and contaminants. However, its integration with biological treatment poses challenges due to the inhibitory effects of elevated NaCl concentrations on microbial activity. To mitigate this issue, a sequential treatment strategy could be implemented, wherein coagulation is followed by a desalination process such as reverse osmosis or electrodialysis to reduce NaCl levels before biological treatment. Alternatively, incorporating halotolerant or halophilic microorganisms, which can thrive in higher salt concentrations, may enhance the biological stage. Furthermore, optimising the NaCl concentration to the minimum effective dose for coagulation could minimise its adverse impact, leading to a more efficient and sustainable treatment system.

Acknowledgement

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through TIER 1 grant (Q405) and GPPS (Q317). In addition, the authors would like to express their gratitude to the people at Faculty of Civil Engineering and Built Environment at Universiti Tun Hussein Onn Malaysia for their assistance throughout the study.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the paper's publication.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Muhammad Hakim Abdul Rahman Adrin, Norhayati Ngadiman, Rafidah Hamdan; **data collection:** Muhammad Hakim Abdul Rahman Adrin, Norhayati Ngadiman, Rafidah Hamdan; **analysis and interpretation of results:** Muhammad Hakim Abdul Rahman Adrin, Noorul Hudai Abdullah, Zuhair Siddiqui; **draft manuscript preparation:** Muhammad Hakim Abdul Rahman Adrin, Norhayati Ngadiman. All authors reviewed the results and approved the final version of the manuscript.

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