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Removal of Turbidity from Muar River Water Sample using Roselle Seeds and Aloe Vera Gel as Biocoagulant

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Abstract

Water pollution has become a global concern to be taken serious action, including Malaysia. In Malaysia, Muar river is considered important water sources as one of the longest rivers, that supply to communities and use in various applications, including fisheries, irrigation, recreational activities, household, agricultural and industrial areas, which currently are slightly polluted due to rapid industrialization and improper waste management. Current treatment of chemical coagulants removes contaminants, yet it has cause toxic sludge which required for a transition to biocoagulant. This study aims to analyse the turbidity removal in Muar river, the effectiveness of Roselle seeds as plant-based biocoagulant, the feasibility of Roselle seeds with and without the help of biocoagulant aid, Aloe vera gel, together with the optimal condition of coagulant dosage and pH using jar test optimization. Turbidity removal is achieved 94.75% without biocoagulant aid while 82.61% with Aloe vera gel. The results shows that plant-based biocoagulant is effective and feasible to be applied in water treatment which encourage sustainable alternative to be utilized worldwide.

1. Introduction

Water, an important resource in sustaining life and ecosystem, especially it has been used in various activities such as drinking water, washing, bathing, cooking, agricultural and in industrial processes. Water is also needed not only for human beings but also for animals, specifically aquatic animals, that requires a clean water source for living. Water is needed to stay hydrated which is beneficial for human health and vital to maintain the health of ecosystems where it will be distributed globally through the natural water cycle [1]. However, water pollution has become a serious environmental issue worldwide due to urbanization, the expansion of industrial areas and agricultural activities. This contamination towards water bodies has affected every consumer in terms of health and the balancing of the ecosystem. In Malaysia, one of the primary sources of water are rivers, that help in supplying to domestic, agricultural and industrial purposes. Studies show that the Muar river contains detectable value of heavy metal and high turbidity, which may exceed the limit set by Malaysia's National Water Quality Standards (NWQS). Although the pH of Muar river is in a good range, the disturbance cause by turbidity and heavy metal affects the value of dissolved oxygen and conductivity.

There are conventional methods that rely on chemical coagulants. that are effective in reducing the pollutant but create a harmful sludge which demands a high operational cost to treat. These issues have increased the interest in producing a safer and natural choice to create a sustainable and friendly environment. The natural method chosen by using a plant-based coagulant, a biocoagulant, to replace alum since natural coagulant is biodegradable, cheaper than chemical coagulant, can be found easily and reduces the environmental impact [2].

Most of the studies on biocoagulant reveals that it has potential in treating water by producing a similar efficiency as alum, helps in reducing turbidity, suspended solids and heavy metals removal. It appears that the effectiveness of biocoagulant is an advantage to be used for water treatment applications.

Roselle is one of the natural coagulants that can be found in tropical and subtropical regions, including Malaysia, where its calyces are commonly used for medicinal, food and beverages [3]. Even so, its seeds are often discarded as agricultural waste despite having rich content in protein, polysaccharide and phenolic compounds that can act as active agents in coagulation and flocculation [4]. These positively charged biomolecules can destabilize the negative charged particles and bind with heavy metal ions. The capability of destabilizing negative charge particles makes Roselle seeds as one of the options for biocoagulant in water treatment. Complementing this, Aloe vera gel has also been recognized as biocoagulant and even act as coagulant aid due to its high content of polysaccharides and other functional groups like hydroxyl and carboxyl that could strengthen the floc formation and improve the efficiency of water treatment. Previous studies proved the potential of Aloe vera in reducing the water quality parameters such as suspended solids, turbidity and even removing certain metal ions when it is combined with chemical coagulant. A study mentioned that Aloe vera gel as coagulant aid has been approved effectively in water treatment [5]. This approach produces a sustainable and cost-effective alternative by mixing up Roselle seeds and Aloe vera gel in the treatment of turbidity and heavy metal removal from the Muar river.

This study aims to analyse the concentration of turbidity in Muar river and evaluate the effectiveness of Roselle seeds as biocoagulant for turbidity removal, by investigating the feasibility of Roselle seeds focusing on the pH and coagulant dosage requires in water treatment. The study includes the water quality parameters such as turbidity, pH, dissolved oxygen (DO) and conductivity that are correlated between one another based on the removal efficiency of turbidity from the Muar river to obtain the clean water through the coagulation and flocculation process. It also benefits the global economy and Malaysian government for advancing sustainable water treatment practices using Roselle seeds as plant-based biocoagulant with less environmental impacts and align with United Nations Sustainable Development Goals (SDG) 6 on improving water quality while SDG 12 promoting sustainable use of resources.

2. Materials and Methods

2.1 Water Sampling

The Muar river is selected for sampling because it is the mainstream for water sources in northern Johor, specifically for the Muar district, that supplies to the local community. The water sampling point is a nearby jetty as hotspot location for the local community to earn for living, ride a water taxi, fishing and high potential of heavy metal contamination to occur because of uncontrolled waste disposal and boat maintenance. The Panchor jetty with a latitude of 2.17307° and longitude of 102.71103° is chosen for the sampling point due to its strategic location where the community of the area normally gather. The jetty has been established in the River Adoption Programme so it is quite lively there with many activities held almost every month.

Not only that, Muar river in Panchor is surrounded by several stalls, restaurants, night markets on Sundays and even early in 2025, a food court is built near the jetty [6]. It makes the location suitable for water sampling where it may build up more contamination from humans' activities that carry purposes for this research in river water treatment. The sample is taken at the jetty as early as possible, around 8 a.m. to 12 p.m., since temperature can change the water conditions and could affect the physical and chemical properties observed in this study [7]. Once the water sample is obtained, it is recommended that the in situ water quality testing be conducted, however, due to limited equipment, the sample is taken to the laboratory and being analysed ex situ within 24 hours. Only some physical and chemical properties are monitored in this research due to time constraints.

2.1.1 Analytical Method on Water Treatment

The Muar river is analysed for its turbidity, pH, DO and conductivity. Turbidity is checked using TN100-IR Portable Turbidity Meter and HANNA Turbidimeter with a resolution of 0.01 to 1000 NTU. The turbidity of river water supposed to be approximated at 10 to 20 NTU yet it may reach around approximately 50 NTU [[8]. Even so, the standard of water quality for turbidity should be 5 NTU and below. If the data collected is above that range, water treatment is needed. Besides, pH, DO and conductivity are measured using Hanna Instrument Edge for each specific measurement of benchtop portable meter. The pH can be detected at low pH of pH 1 and at high pH of pH 14 [9]. This study will be using pH 2 and pH 5 for acidic conditions with pH 9 and pH 11 for alkaline conditions while pH 7 for neutral. These adjustments are made to achieve the objectives of optimal conditions that work best for Roselle seeds. As for Hanna DO meter, the range for data to be detected is within 0 to 45 mg/L while Hanna conductivity meter can detect at 100 to 999 µS/cm. All the meters are cleaned with distilled water to remove impurities that stained on the probe and may disturb the reading [10]. Once all data are obtained from every process, it will be inserted to Google Sheets for analysis and producing a better visual context for understanding.

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2.2 Sample Preparation

The preparation of natural coagulants is a vital stage in this study as the efficiency of the coagulation process depends on purity and particle size of the sample. In this study, the main biocoagulant used is Roselle seeds while Aloe vera gel acts as coagulant aid in the treatment. Both coagulant materials are obtained from a local community based in Muar, Johor. Roselle seeds are dried in the oven at 50°C for 24 hours to remove moisture content without denaturing the active coagulation compounds. The dried seeds is ground and sieve using 150 µm before kept in an airtight container. Aloe vera gel is separated from the rind, blend to homogenous liquid and stored in a chiller to maintain its compound.

After the preparation of raw materials is completed, the stock solutions are prepared by dissolving the prepared Roselle seeds and Aloe vera gel in distilled water. 1 g of Roselle seeds powder and Aloe vera gel, respectively, is weighed and mixed in a volumetric flask of 1000 mL distilled water. Although there are alternative formulations for preparing stock solution by dissolving the raw ingredients in NaOH, NaCl and HCl [11], distilled water is chosen as a safest and sustainable solvent to be used for both humans and environments. These solutions are agitated for 30 minutes to ensure the active substances are fully suspended and is kept in a chiller below 4°C to 7°C to maintain the mixture.

2.3 Coagulation and Flocculation

The river water collected from Panchor Jetty is prepared in six beakers of 1 L with an amount of 200 to 500 mL. The jar test is conducted using conventional six jar test apparatus (Velp Scientifica Flocculator JLT 6) with three alternative mixing modes of rapid mixing, slow mixing and settling [12]. In most studies, rapid mixing is performed for 1 to 3 min at speed of 120 rpm to 160 rpm to enhance the floc formation while slow mixing is manipulated at 30 to 40 rpm for 15 to 40 min. As for settling time, it depends on the floc size and volume formed in the jar but normally, 30 min and above is set in this mode. For this study, the jar test starts with 3 min of rapid mixing (120 rpm and160 rpm), followed by slow mixing for 40 min at 40 rpm and then 30 min of settling.

The raw water conditions are checked for turbidity, pH, conductivity and dissolved oxygen before the jar test is conducted. The pH of river water is adjusted using 1 M HCl or 1 M NaOH to ensure the effectiveness of chemical processes as some biocoagulant work better in acidic conditions as Roselle seeds while some biocoagulant perform best in alkaline conditions [13]. The pH for jar test is modified from pH 2 to pH 11 to identify the optimization of biocoagulant in water treatment. Other than that, coagulant dosages are manipulated in the range of 10 mL to 40 mL as a part of the research design.

3. Result and Discussion

3.1 Muar River Characterization

Based on Department of Environment (DOE), the Muar river is slightly polluted that is classified from water quality index (WQI). This pollution may be affected by the food court, restaurant, cemetry, night market, residential area nearby the Panchor jetty and from the activities held at the jetty itself. Along the waterway, near the main Muar river, there are several industrial areas that may be potential sources of pollution to occur other than impact of natural processes [14]. This evidence justify the importance of water treatment is processed in a lab-scale. The data collected for Muar river characterization in Panchor is shown in Table 1.

Table 1 *Muar River characterization*

Parameters	Muar river	National Water Quality Standards	Drinking Water Quality Standards
Turbidity (NTU)	62.98	1000*	5*
pH	6.4	5.5-9.0**	6.5-9.0***
Dissolved oxygen (mg/L)	7.22	5-8**	6.5-9.0***
Chemical oxygen demand (mg/L)	50	10-25	7**
Conductivity (µS/cm)	150	>1000*	>1000*

The parameters in Table 1 are a comparison of the national water quality standard, water quality standard for drinking water and Muar river characterization. The data of the Muar river is obtained from the initial water quality check after collecting the sample from the source. The data for NQWS and drinking water quality standards is achieved from several sources. Generally, the water quality parameters set by the WHO has become the guideline for all authorities to have a baseline worldwide. It shows that the turbidity value should be around 1000

Nephelometric Turbidity Unit (NTU) and below which is same goes to conductivity, according to World Health Organization (WHO) guideline while 5 NTU and below is required to be achieved for drinking water quality [15].

In addition, DOE Malaysia have come out with regulation standard for water quality standards where COD value must be around 10 to 25 mg/L while DO of 5 to 8 mg/L is needed with 7 mg/L for drinking water. Also, the value of pH for raw water should be around pH 5.5 up to maximum of pH 9 [16]. According to [17], they have a standard especially for drinking water where pH baseline should be around pH 6.5 to pH 9.0 and COD should be approximately 10 mg/L. The changes in pH value may cause the taste of water turns bitter, sour or metallic [18].

3.2 Effect of pH and Coagulant Dosage on Turbidity

The result obtained from four set of experiments shown that the optimum pH and coagulant dosage (RSE/AVG) for both biocoagulants, Roselle seeds and Aloe vera gel, are pH 2 and 40/20 mL. Although the result for turbidity removal efficiency of Roselle seeds is high 94.75%, with the help of Aloe vera gel has increased the removal efficiency of turbidity to 95.50%. The data in Table 2 shows the data for pH and coagualant dosage testing using Roselle and Aloe vera as biocoagulants. The data are compared with the previous studies that are using the same biocoagulants for water treatment.

Table 2 *Comparison of experimental results and previous studies for pH and coagulant dosage*

Biocoagulant	pH	Coagulant Dosage	Turbidity Removal Efficiency	References
Roselle seeds and aloe vera gel	2	Roselle = 10 mL	95.50%	-
	5	Aloe vera = 10 mL	6.60%	-
	7		9.10%	-
	9		3.00%	-
	11		4.40%	-
	2	Roselle = 40 mL	82.61%	-
		Aloe vera = 20 mL		
	2	Roselle = 20 mL	15.80%	-
		Aloe vera = 20 mL		
	2	Roselle = 20 mL	20.80%	-
		Aloe vera = 40 mL		
Roselle seeds	2	190 mg/L	81.31%	[23]
	5		~50.00%	
	7		~45.00%	
	9		~35.00%	
	11		~30.00%	
	3		88.55%	
Aloe vera powder	7	0.5 g	72.91%	[24]

	11	40 mL	67.90%	-
	2		94.75%	
Roselle seeds	2	40 mL	72.83%	-
Aloe vera gel	7	5 mL	72.16%	[25]

3.3 Removal Efficiency of Turbidity

The removal efficiency of turbidity in treated water sample is shown in Figure 3 with a triplicate data using three samples (3,4 and 7) for optimization testing on the effectiveness and feasibility of RSE in turbidity removal from Muar river. The results show the difference between three coagulant dosages with same pH.

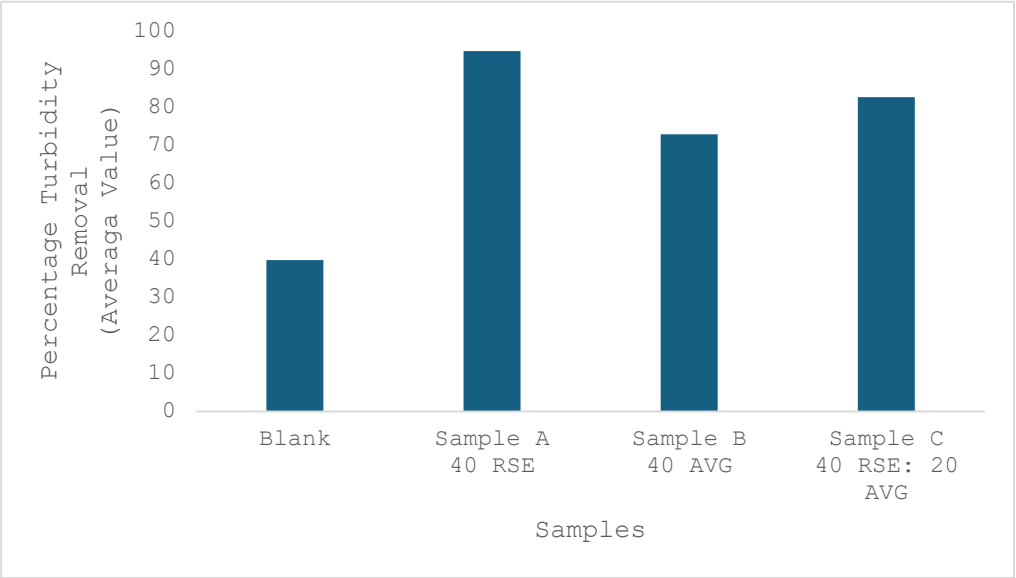

Figure 3 *Turbidity removal percentage with triplicate samples*

The removal efficiency for RSE is higher than AVG and produces almost the same percentage of 95.58% for RSE with coagulant aid, AVG when compared to without the coagulant aid (95.30%). This explains that either with the help of coagulant aid, or without coagulant aid, RSE can remove the pollutant in river water, especially in Muar river. This application of RSE can be used for water treatment plants where less sludge is produced during the experiment.

The turbidity for AVG may be unsuitable for drinking water (14 NTU), however according to NQWS, it is still acceptable for river water that is categorized as a water supply for various purposes. Also, the data obtained for AVG is quite high of 91.41% lesser than a study of [20] that reaches the removal percentage of 98.21%. It shows that AVG is a guaranteed alternatives for water treatment either as biocoagulant or coagulant aid. This assessment expressed the quality of both plant-based coagulants are certified as natural alternative to chemical coagulant which should be established worldwide.

3.4 Correlation between Water Quality Parameters

A comprehensive study has been made and after some observations, it seems that the changes of pollutants have correlation between one another. The study focuses on turbidity removal that is related with DO and conductivity in river water. The increasing value of turbidity has affected DO by reducing the value in river water. This happen when the cloudiness of water become blockage for sunlight to reach the organism in it which then prevent the reaction of DO. Besides, DO is also related to heavy metal ion in the river according to [21] where the decreasing of DO in river water influenced the heavy metal in water sample. Not only that, but heavy metal concentration is also related to the water quality parameters such as DO, pH and conductivity. This statement is supported by research of [22] where DO plays an important role for heavy metal content especially Pb and Cu in sample. DO controls the behaviour of heavy metal by increasing the mobility if the value is high and bind the metal once the value of DO low.

4. Conclusion

As a conclusion, the treatment of Muar river is achieved for this study since the turbidity concentration is obtained with 62.98 NTU and classes as a slightly polluted river in Malaysia. After the jar test is done with several trials, turbidity removal is achieved successful using RSE without and with the aid of AVG. The chosen coagulant dosages are 40 mL of RSE and AVG respectively with 20 mL AVG is added into 40 mL RSE. The second objectives is established for turbidity removal and show the effectiveness of Roselle seeds as biocoagulant in water treatment. As for the last objective, the dosage is determined after adjusting the pH to pH 2 in jar test optimization.

The process requires improvement for the future applications in water treatment either in small or big scale. This study may benefits people with limited sources or having a lot of plant-based coagulant that can be used for further application of green technologies. It complies with the SDG 6 by achieving the improvement of water quality by reducing hazardous chemical and ensure safe access to clean water while SDG 12 promoting the sustainable use of resources, the plant-based biocoagulants. This eco-friendly solution may assist the water treatment to gain a more sustainable alternatives in the future.

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