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The Effect of Cactus Opuntia and Banana Pith as Bio-Coagulant in Water Treatment

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Coagulation and flocculation are crucial processes in the treatment of surface water and industrial wastewater or raw water. These processes typically involve the use of inorganic chemical coagulants, such as alum and ferric salt. However, these coagulants come with significant drawbacks, including high procurement costs and adverse effects on human health and the environment. This study explores the natural coagulation process as an alternative to conventional raw water treatment. The objective is to develop a natural bio-coagulant from cactus opuntia, banana pith, and a small amount of polyaluminum chloride (PAC) chemicals, capable of treating river water for daily use especially in water treatment process. PAC is a highly effective coagulant used in water treatment processes. It has several applications due to its ability to remove impurities and contaminants efficiently. Additionally, the study investigates the effectiveness of banana pith and cactus opuntia as bio-coagulants in reducing river water pollution. The methodology involves using river water filled into six beakers, followed by the addition of natural bio-coagulant materials with specific ratio as per the established procedure. The materials are cut, and either heated or ground before being added to the water. After filtering, the mixture is placed in a beaker with raw water for treatment. The materials physical properties and chemical compositions, including liquids and solids, affect the water's pH, turbidity, and color. Based on the literature, factors such as water type, coagulant material, material mass, temperature, and time are considered. The treated water showed a reduction in turbidity from 94.6 Nephelometric Turbidity Unit (NTU) to 9.64 NTU and a pH level of 6.05 approaching to natural pH value, with successful reduction of four heavy metals: iron, copper, manganese, and chromium.

Keywords: Cactus opuntia; banana pith; bio-coagulant; water treatment; water pollution

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The Muar River water will serve as the experimental material due to its role as a key source of raw water for daily consumption and its ease of access. The experiment will treat river water samples using a natural coagulant combined with a small amount of PAC. These samples will be placed in several beakers and monitored for a duration of 20 to 60 minutes. This time frame will allow for an evaluation of the coagulant's effectiveness and the impact of varying coagulant dosages. The raw river water contains multiple parameters, including COD (Chemical Oxygen Demand), ammoniacal nitrogen, nitrate, suspended solids, turbidity, chloride, calcium, zinc, magnesium, potassium, sodium, cadmium, iron, and pH levels, as outlined in **Table 1** [1]. To enhance the water quality, effective natural coagulants, such as cactus opuntia, known for its high turbidity reduction, and banana peel, which aids in attracting iron, were used. Several coagulant compositions and concentrations were tested to assess their performance.

A significant issue identified is the lack of attention given to the use of cactus opuntia and banana pith in Malaysia. There is very little information on producing natural bio-coagulants from these materials, even though studies in other countries, such as India, have explored this [1]. Furthermore, the water treatment industry has traditionally depended on chemical coagulants, partly due to limited awareness of their long-term health effects. Extended exposure to chemicals like aluminum chloride, which contains neurotoxins, poses health risks. Research shows that aluminum accumulates in tissues such as the kidneys, liver, bones, and brain, potentially leading to severe health conditions like dementia and other neurological disorders [2].

Flocculation with synthetic flocculants made from artificial polymers presents environmental and health hazards because of their persistence and resistance to degradation [3]. To address these concerns, there is a growing demand for safe, biodegradable flocculants. This research investigates the potential of utilizing banana and cactus opuntia to create natural flocculants that are biodegradable, non-toxic, and also enable the repurposing of sludge as fertilizer.

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Table 1. Muar river water treatment.

		R^2	Different (R^2AP)-R^2	Contribution %
All parameter		0.901848		
Conductivity, Salinity, DS, TS,Cl, Ca, K, Mg, Na	D1	0.894891	0.006957	2.493
Cd	D2	0.898588	0.003260	1.168
SS, TUR	D3	0.858842	0.043006	15.409
pH	D4	0.757977	0.143871	51.547
COD, *E.coli*	D5	0.890012	0.011836	4.241
COD, NH_3	D6	0.848334	0.053514	19.173
NO_3	D7	0.883738	0.018110	6.489
Fe	D8	0.903298	-0.001450	-0.520
Total			0.279104	

Coagulation and flocculation can be achieved using either natural or chemical coagulants [4]. Historically, natural coagulants have played a significant role in traditional water purification, with their use documented in various ancient texts. Since the 1880s, metal-based coagulants such as ferric salts have been widely used in water treatment across the United States [5]. The introduction of polymerized aluminum coagulants, particularly polyaluminium chloride (PAC), has further shifted the focus toward chemical solutions due to their higher efficiency and lower alkalinity requirements. However, the dominance of chemical coagulants has largely overshadowed natural alternatives, which are now primarily utilized in rural or developing regions where access to chemical coagulants is limited [5]. As a result, the water treatment industry has become heavily reliant on chemical coagulants for turbidity control.

The research findings are anticipated to greatly improve water quality. During the flocculation stage of water treatment, the application of natural bio-coagulants will effectively cleanseb the water. These coagulants function by using negative ionization to attract and bind positive ions from turbidity particles, forming larger aggregates known as flocs. These flocs can then be easily separated through subsequent solid-liquid processes. For example, the mucilage in cactus opuntia contains a polymeric polysaccharide that efficiently absorbs turbidity, while banana pith is recognized for its ability to remove iron from water [6]. As a result, the treated water is expected to exhibit a balanced pH, clear appearance, and low turbidity, making it safe for everyday use. Moreover, natural bio-coagulants offer a cost-effective alternative to chemical coagulants, which are typically expensive. This project aims to reduce material costs while enhancing the overall efficiency of the water treatment process.

EXPERIMENTAL

Chemicals and Materials

The primary material for this project is Muar River water, due to its proximity and significance to the study. As a crucial water supply for local residents, the Muar River is well-suited for examining the water treatment process. The river water contains various elements, such as pH levels, dissolved gases, suspended solids, turbidity, color, and heavy metals. In the experiments, the water will be divided into several 500 ml beakers, with each sample being treated using measured amounts of natural coagulants along with a small addition of chemical coagulants to enhance the overall effectiveness of the treatment.

In this study, cactus opuntia is used as the primary natural coagulant. The cactus pads, measuring between 10 centimeters (cm) and 15 cm, are first halved to extract the mucilage. The mucilage is then separated from the pads and placed into a 500 milli litter (ml) beaker. It is categorized into quantities ranging from 0 grams (g) to 50 g, after which it is processed in a grinder to obtain either an aqueous or gel form. This ground mucilage is then combined with 500 ml of river water, along with a filtered banana coagulant. A jar test is subsequently performed, involving agitation to homogenize the mixture and prepare it for coagulation [6].

Banana pith is employed as the second natural coagulant in this study. The pith, taken from bananas approximately 20 cm in length, is initially cut into smaller pieces to facilitate handling and weighing. This process results in an average banana pith weight of 127.78 g.

Table 2. Matrix table for dosage.

BEAKER	BANANA	CACTUS	PAC
1	50 ml	0 g	1 ml
2	40 ml	10 g	1 ml
3	30 ml	20 g	1 ml
4	20 ml	30 g	1 ml
5	10 ml	40 g	1 ml
6	0 ml	50 g	1 ml

Characterization Methods

In a 1000 ml beaker, 500 ml of distilled water is combined with banana pith. This combination is blended for 5 minutes until the banana pith dissolves completely, resulting in a smooth solution. The mixture is then filtered through a paper filter to remove the coagulant from the banana pith [7].

Natural ingredients like Cactus opuntia and banana pith are initially cut into smaller pieces with a knife. These pieces are then measured using a beaker. The Cactus opuntia is dried in an oven at 80 degrees Celsius (°C) for 24 hours [4]. On the other hand, the banana pith is not dried; it is instead combined directly with distilled water and blended.

Once dried, the Cactus opuntia is ground into a fine powder. This powder is then mixed with distilled water to form a uniform solution. The mixtures of both Cactus opuntia and banana pith are filtered through filter paper to isolate the liquid coagulants, following the ratios specified in **Table 2.**

RESULTS AND DISCUSSION

Following a series of tests that utilized Cactus opuntia and banana pith as natural coagulants for treating river water, the optimal combination was identified as 30 ml of banana pith and 20 g of cactus opuntia, along with 1 ml of PAC in 500 ml of water. This mixture significantly improved water quality, achieving a pH level between 6.0 and 7.8, which was considered safe for use. The turbidity of the treated water decreased dramatically by 89%, dropping from 94.6 NTU to 9.64 NTU. Furthermore, the sample effectively reduced the concentrations of four heavy metals: iron (Fe), copper (Cu), chromium (Cr), and manganese (Mn). Data collection and analysis included the use of a pH meter to measure water pH, a UV spectrometer to detect heavy metals, and a portable turbidity test kit to assess turbidity levels.

pH Value

Among the six samples tested, the third sample achieved a nearly natural pH of 6.05. However, the remaining samples did not fall within the ideal pH range of 6 to 8, which was considered optimal for water quality. **Figure 1** below illustrates the pH values recorded for each sample.

The graph in **Figure 1** illustrates the pH values of water for each beaker sample. Sample 3 exhibited the most suitable turbidity. At this optimal pH, the coagulant hydrolyzed to form positively charged metal hydroxides, which neutralized the negatively charged particles in the water, leading to effective coagulation. In contrast, samples 1 and 2 had pH values below 6, indicating acidity due to the high dosage of banana. Similarly, samples 4 and 6 also had pH levels below 6, resulting from excessive cactus dosage. Finally, although sample 5 had an acceptable pH, its turbidity remained high, exceeding 10 NTU.

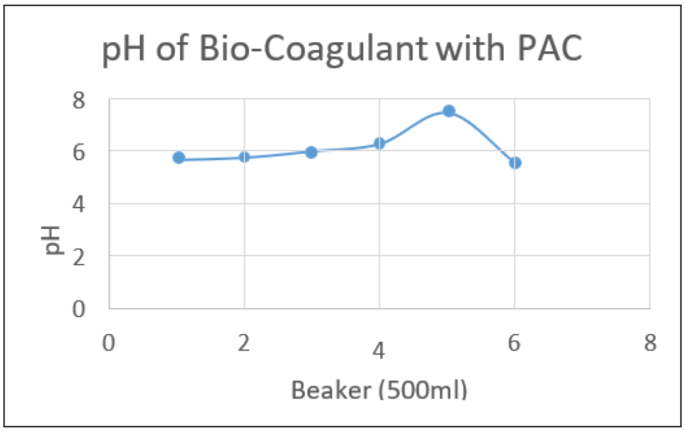

Figure 1. Graph of pH value.

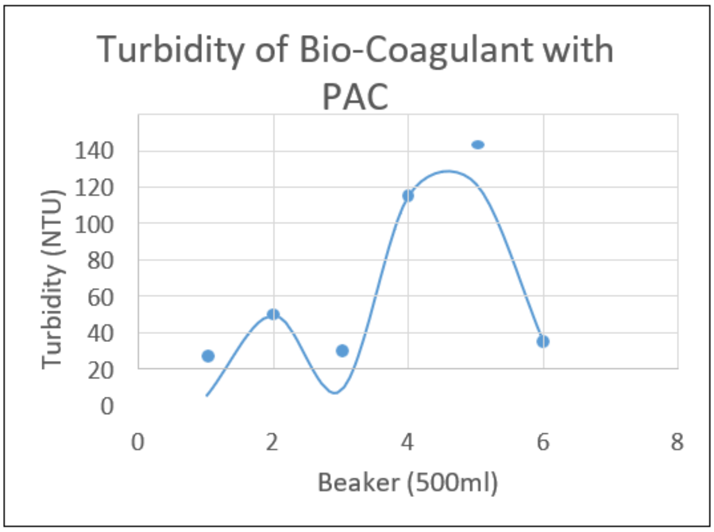

Figure 2. Graph of turbidity value.

Turbidity Value

The turbidity removal results for the six sample beakers were shown in **Figure 2**. Among these, two beakers displayed low turbidity levels: Sample 1 at 6.47 NTU and Sample 3 at 9.64 NTU. However, Sample 1 exhibited a pH anomaly of 5.72, as noted in the earlier pH results. Consequently, Sample 3, with both acceptable turbidity and pH levels, was identified as the most appropriate choice for use.

The graph in **Figure 2** displayed the turbidity values of water for each beaker sample. Sample 3 was the most suitable for use, with a low turbidity of 9.64 NTU, minimizing residual metal ions that could affect downstream processes and the quality of treated water. In contrast, Samples 2, 4, 5, and 6 exhibited high turbidity levels exceeding 10 NTU, with values of 50.96 NTU, 116 NTU, 122.3 NTU, and 36 NTU, respectively. This imbalance was attributed to excessive volumes of banana and cactus dosages. Although Sample 1 had an acceptable turbidity value of 6.47 NTU, its pH was below 6 (5.72), rendering it too acidic for use.

Heavy Metal Value Removal

The experiment used a spectrophotometer to measure heavy metal levels in river water across seven beakers. Sample 7, which contained untreated river water, served as a baseline, while the other beakers were treated with a mixture of cactus, banana pith, and PAC. The goal of the analysis was to evaluate the treatment's effectiveness in reducing heavy metal concentrations. Samples with lower heavy metal content were considered safer for use, while those with elevated levels posed potential risks to the skin. The results showed that Sample 3 had the lowest concentration of heavy metals, making it the most suitable option, as shown in **Table 3** below.

Table 3. Heavy metal removed in each beaker.

Sample	Iron (Fe)248.3	Cooper (Cu) 324.8	Chromium(Cr) 357.9	Manganese(Mn) 279.5
1	0.3723	0.1317	0.1101	0.2595
2	1.1517	0.5144	0.3400	0.7896
3	0.8011	0.3721	0.1823	0.5164
4	2.3684	1.2294	0.8086	1.7121
5	2.4677	1.2282	0.7469	1.7319
6	1.4842	0.7927	0.3689	1.0004
7	0.8867	0.5781	0.4814	0.7471

CONCLUSION

This project successfully achieved its objectives and was implemented effectively. In summary, the research findings indicated that the third beaker, out of the six tested, performed the best. It achieved a favorable pH of 6.05, a turbidity level of 9.64 NTU, and a low concentration of heavy metals. These results were promising and aligned well with the project's objectives, which aimed to reduce water turbidity, achieve an optimal pH, and decrease heavy metals such as iron (Fe), copper (Cu), chromium (Cr), and manganese (Mn). This ensured that the treated water was suitable for everyday use, meeting the project's goals.

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