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Comparative Study on Treatment of Wastewater Using Natural and Artificial Coagulants

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Abstract: This study compares the effectiveness of bamboo charcoal and alum in wastewater treatment for pH, turbidity, Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), and Dissolved Oxygen (DO) using the Malaysia Water Quality Index. The wastewater was collected at UTHM Campus Pagoh Cafeteria. The characterisations of bamboo charcoal were examined by using the Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR) and Energy Dispersive X-ray (EDX) analysis. Next, the jar test was conducted with bamboo charcoal then continued with alum by varying the coagulants dosage (10 mg/L, 20 mg/L, 30 mg/L, 40 mg/L, and 50 mg/L) and pH values (4, 6, 8, 10, and 12) to define the optimum dosage and pH. From the findings, the optimum dosage for bamboo charcoal and alum is at 30 mg/L, and the optimum pH is 8. Recorded the performance of bamboo charcoal coagulant that removed 73.73 % of turbidity, 48.73 % of TSS, and 52.84 % of COD. In contrast, alum removed 88.39 % of turbidity, 61.82 % of TSS, and 69.05 % of COD. However, this study had achieved the objectives stated after-treatment of the wastewater with the natural and artificial coagulants, although below the permissible limit prescribed by the Environment Quality Act.

Keywords: Wastewater Treatment, Natural Coagulant, Bamboo Charcoal, Alum

1. Introduction

Urbanisation and industrialisation cause the wastewater increased day by day [1]. Apart from the increasing demand for fresh and wastewater production. Furthermore, wastewater treatment directly affects the biological diversity of the marine ecosystem and has a substantial influence on the life support systems. Thus, wastewater treatment is a crucial environmental element and affects all industries [2].

According to [3], there are two categories of domestic wastewater varying from the source: greywater and blackwater. Each of them has a different level of contamination that needs a different

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type of treatment. Due to bacteria and grease pollution, water from kitchens and dishwashers is also classified as blackwater. It can also carry illness and germs, potentially hazardous by interacting with skin or consuming the water. In contrast, greywater is easier to treat because it contains a lower level of contamination than blackwater. It comes from sinks, showers, and bathtubs. Around 25 years Water Quality Index (WQI) has operated as the basis for environmental evaluation of the water quality in Malaysia, while National Water Quality Standards (NWQS) define the crucial effects of the river [4].

The purpose of water quality analysis is used to determine the needed parameters of water using the standard technique and determine whether they meet the criteria [5]. The wastewater quality parameters were conducted based on the desired water parameters of concern. There are many parameters of wastewater quality. The three typical wastewater quality parameters include physical, chemical, and biological parameters [6]. The biological parameter is the presence of the living organism as the indicator [7].

One of the wastewater treatments is coagulation. Coagulation is a process utilising chemical coagulant mixed with water, and various species of positively charged particles adsorb to negatively charged colloids to produce microflocs. When the reaction happens, the particles coagulate, called microflocs. The microflocs are entirely imperceptible for the human eye. The additional coagulant may require if the water around the freshly created microflocs is not clear because the charges of particles not fully neutralised, and no coagulation occurred. The colloids formed unstably and the coagulation occurred and followed by flocculation [8].

2. Materials and Methods

This study is limited to the wastewater treatment at UTHM Pagoh Campus. The entire endeavour would begin with data collection and theoretical investigations before starting to conduct the several parameters for the wastewater. The samples were collected using the grab sampling method within 6 weeks from November-December 2021 at 11 a.m. Each sample has the same level of wastewater collected were stored in a chiller at the laboratory. Sampling and sample preventions were based on Standard Methods for the Examination of Wastewater [9]. After the natural coagulant was prepared, the chemical characteristics of natural coagulants determine by using the Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), and Energy Dispersive X-ray (EDX) analysis. Next, the jar test was conducted with bamboo charcoal then continued with alum by varying the coagulants dosage (10 mg/L, 20 mg/L, 30 mg/L, 40 mg/L, and 50 mg/L) and pH values (4, 6, 8, 10, and 12) to define the optimum dosage and pH. The result of parameters were obtained such as pH, turbidity, Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), and Dissolved Oxygen (DO). The results of the performance of coagulants were analysed and compared according to Malaysia Water Quality Index.

2.1 Preparation of the alum coagulant

Prepare a stock alum solution by dissolving the Aluminium Sulphate powder according to dosage needed as 10 mg/L, 20 mg/L, 30 mg/L, 40 mg/L, and 50 mg/L in 1 litre distilled water. The stock solution prepared in the different concentration [10]. Avoid the stock solution of alum interact directly with skin.

2.2 Preparation of the bamboo charcoal coagulant

Bamboo are prevalent in Asia-Pasic areas [11]. Bamboo Vulgaris commonly plant in Nigeria and it has high-level of accumulation rate [12]. Besides, it can move the heavy metals and utilise the negative surface charge of bamboo by induced the pH value to remove the metal ion in solution. Artificial coagulants commonly used for wastewater treatment are Aluminium and Iron salts. Alum as known as aluminium sulphate is the most prevalent for treatment of water and widely used in treatment plants [13]. Using the artificial coagulant, these processes are efficient at eliminating fine suspended particles that appeal and hold bacteria and viruses to their surface. The disadvantages usage of these coagulants such as comparatively high cost, harmful effects on human health as well as affect ecosystem also the fact that they appreciably affect pH of treated water [13].

2.3 Coagulation test

The jar testing determines the efficiency of natural and artificial coagulants used in this study. The dosage of the alum and bamboo charcoal coagulants were calculated in mg/L. There were four sets of jar test for this study to be carried out. Included the varying both coagulants dosage and varying the pH values. This study started with bamboo charcoal coagulant. The 6 units of beakers require in this jar test. Each label beakers fill with 500 ml of samples of wastewater. One beaker of wastewater sample without the addition of any coagulant is a control sample, while the other five beakers fill with the dosage of coagulant according to the Table 1. The dosage was added to the fresh wastewater and mixed using a magnetic stirrer according to mixing speed components. Then, the beakers left about half an hour to let it settle. The optimum dose of each coagulant can be determined from these jar test. The optimum dose is the coagulant quantity that produces the desired effects without any unpleasant effect [14]. Lastly, repeated the steps above by using the varying alum coagulant dosage by fixing the constant, as shown in Table 2. Then repeated the jar test with varying the pH values (4, 6, 8, 10, and 12) by using the optimum dosages of the coagulants.

Table 1: Coagulant dosage for determine optimum dosage

Beakers	Coagulant Dosage
1 (control)	10mg/L
2	20mg/L
3	30mg/L
4	40mg/L
5	50mg/L
6	60mg/L

Table 2: Constant of mixing speed

Components	Value
pH value	6
Rapid mixing (rpm)	200
Rapid mixing duration (minutes)	5
Slow mixing (rpm)	25
Slow mixing duration (minutes)	15
Settling time (minutes)	60

2.4 Analysis of data

The effectiveness of the coagulants used in this study was determined according to the percentage of removal of colour from the wastewater sample and comparison of the removal percentage of colour between single bamboo charcoal, single alum, and the combination of bamboo charcoal and alum made by using the Eq. 1.

$$\text{Percentage removal} = [(C_{initial} - C_{final})/ C_{initial}]\ (100\%) \qquad Eq.1$$

Where,

C = Concentration, mg/L

3. Results and Discussion

This section presents the results and discussion of the study which can be organised based on the objectives that need to be achieved, the flow according to the methodology and the different type of parameters to be carried out. The removal efficiency was determined using the jar test method by varying the dosage, pH values, and mixing speed. According to the Malaysia Water Quality Index, the removal efficiency of wastewater using bamboo charcoal coagulant was then compared with alum.

3.1 Characterisation of the bamboo charcoal powder

The analysis of bamboo charcoal characterisation was conducted before using natural coagulant for wastewater treatment by using FTIR, SEM, and EDX analysis. FTIR analysis examined the primary functional group present in the bamboo charcoal powder, and this technique helps identify the functional groups that can remove the turbidity.

Fourier Transform Infrared Spectroscopy (FTIR) interprets the spectra of bamboo charcoal powder. The spectra display several transmittance peaks shown in Figure 1, indicating the possible chemical functional groups on the bamboo charcoal that treated the wastewater. Several peaks in region between 4000 cm^{-1} and 600c m^{-1} obtained at 3298.93 cm^{-1}, 2113.10 cm^{-1}, 1794.12 cm^{-1}, 1564.99 cm^{-1}, and 1027.00cm^{-1}. The broad peak at 3298.93 cm^{-1} indicated the O-H stretch from the surface hydroxyl group. The frequency band at 2113.10 cm^{-1} identified the weak C≡C stretch from the alkynes group. Another intense transmittance peak in 1794.12 cm^{-1} belonged to carbonyl stretch. Finally, 1564.99 cm^{-1} and 1027.00 cm^{-1} were from the same compound class, amines but had different functional groups: N–H bend and C–N stretch, respectively.

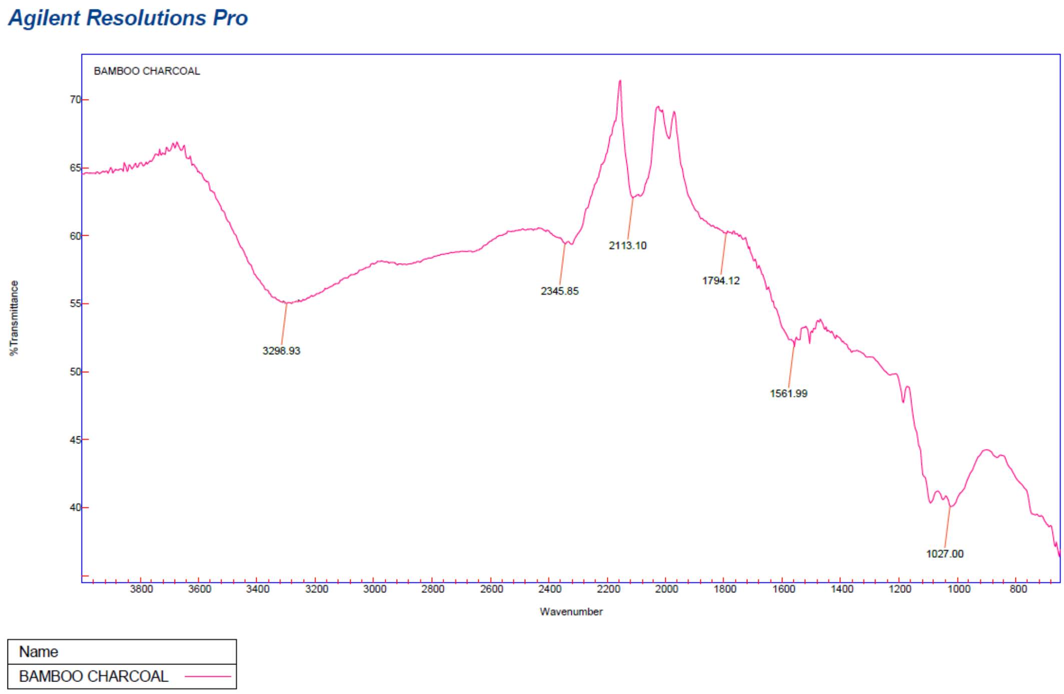

Figure 1: FTIR analysis for bamboo charcoal powder

Scanning Electron Microscope (SEM) analysis examines the surface morphology of the bamboo charcoal powder. Figures 2 shows the surface morphologies of the particles at two different magnifications, such as 2000x and 5000x magnification. By coating the sample of the bamboo charcoal correctly, the smooth surface morphology observed. The surface morphology of the particles looks like a honeycomb. The previous study also stated that the surface morphology of the bamboo charcoal powder looks like a honeycomb [15]. The bamboo charcoal covered in numerous minuscule holes, which make its structure highly porous.

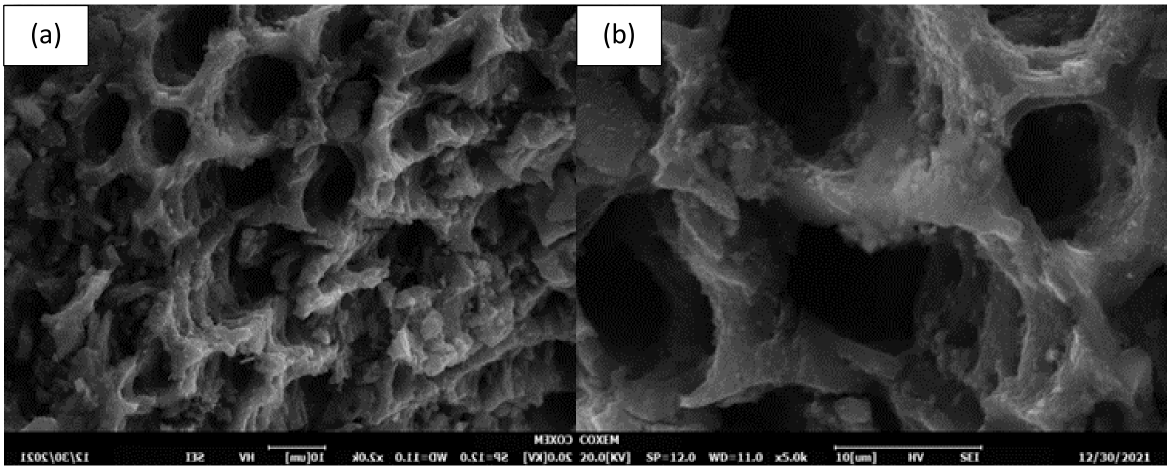

Figure 2: The surface morphology of the bamboo charcoal powder in (a) 2000x and (b) 5000x magnification

3.2 Turbidity removal in varying dosage

The comparison of turbidity removal between bamboo charcoal and alum coagulants in wastewater samples after being treated with the different dosages shows in Figure 3. Both coagulants have the potential to decrease the turbidity level after treating the wastewater. Based on the graph shown, at the different dosages, both coagulants show a similar trend of turbidity removal. Therefore, the optimum dosage for bamboo charcoal and alum was obtained at 30mg/L. Nevertheless, the turbidity of wastewater after being treated with alum is lower than bamboo charcoal because the graph shows that the turbidity removal obtained for alum is higher than bamboo charcoal. The size particle of the coagulant used in this study influenced the positive charge that helps to destabilise the negative charge of the colloidal particle.

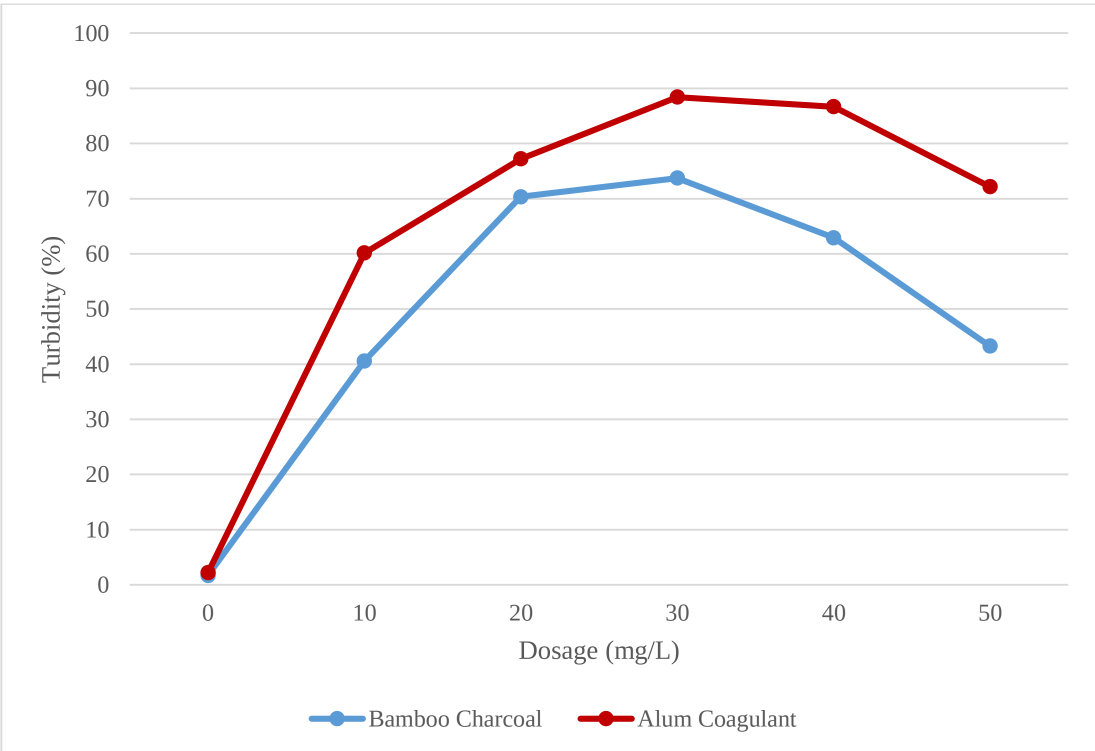

Figure 3: Comparison of turbidity removal between bamboo charcoal and alum coagulant with varying coagulant dosage

3.3 Turbidity removal in varying pH values

Figure 3 presents the results of the optimum pH value by using the optimum dosage of coagulants used in this study. The optimum dosage of both coagulants was already determined. The varied pH values of wastewater samples such as 4, 6, 8, 10, and 12 were added into beakers to identify the optimum pH value for this study. The constant variables for this analysis were the optimum dosage of both coagulants (30 mg/L) and the mixing speed at 200 RPM for 5 minutes, 25 RPM for 15 minutes and settling time for 1 hour. Based on Figure 4, both coagulants observed the highest turbidity removal at pH 8. However, the turbidity removal on alum coagulant (88.28 %) was higher than bamboo charcoal (78.00 %) in wastewater treatment. The lowest turbidity removal for both coagulants was at pH 4 which were 50.51 % for the bamboo charcoal coagulant and 52.28 % for the alum coagulant. The bamboo charcoal coagulant abled to decrease the turbidity by 73.07 %, 67.74 %, and 61.56 % at pH 6, 10, and 12 respectively. While the performances of alum coagulant at pH 6, 10, and 12 were able to remove the turbidity by 87.89 %, 70.19 %, and 63.43 % respectively.

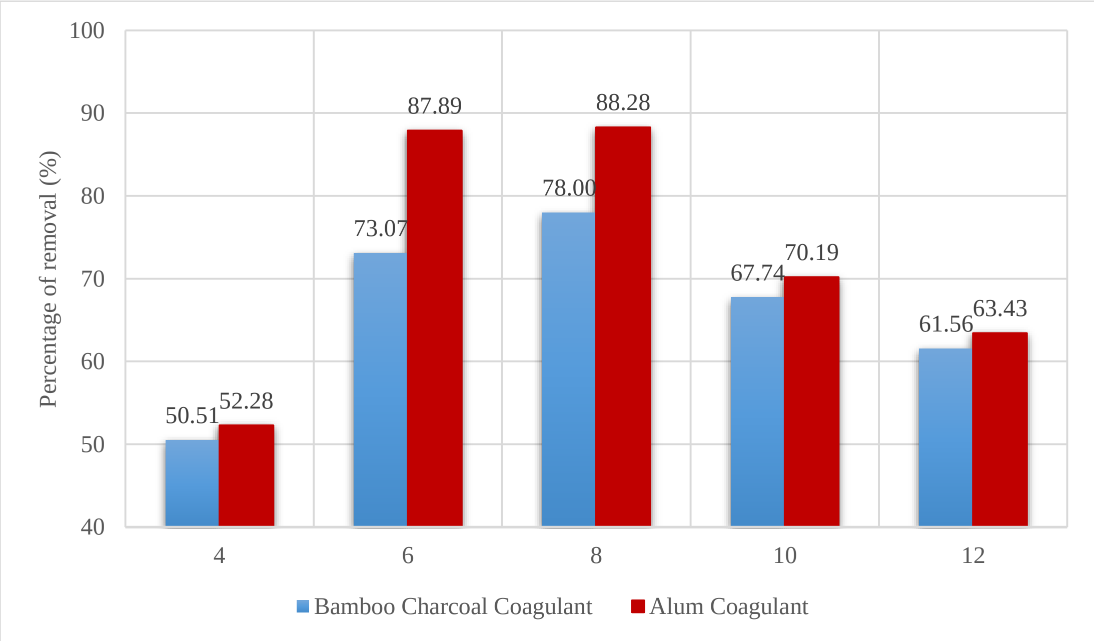

Figure 4: Comparison of turbidity removal between bamboo charcoal and alum coagulant with varying pH values

3.4 Effect of the optimum dosage, and pH

The results of the wastewater parameters on the effect of the optimum dosage, and pH such as chemical oxygen demand (COD) and total suspended solids (TSS) after treated the wastewater. Based on the Figure 5, the COD removal of the wastewater treatment expressed. 465 mg/L is the initial reading average of the chemical oxygen demand of the wastewater. After running the jar test, the data of the chemical oxygen demand was tabulated by using the optimum coagulant dosage, pH, and mixing speed of bamboo charcoal, alum, and the combination of both coagulants. Alum coagulant recorded 69.05 % as the highest percentage of COD removal in this study which the final COD value is 147 mg/L, while the bamboo charcoal recorded 52.84 % as the lowest COD removal which the final COD value is 224 mg/L.

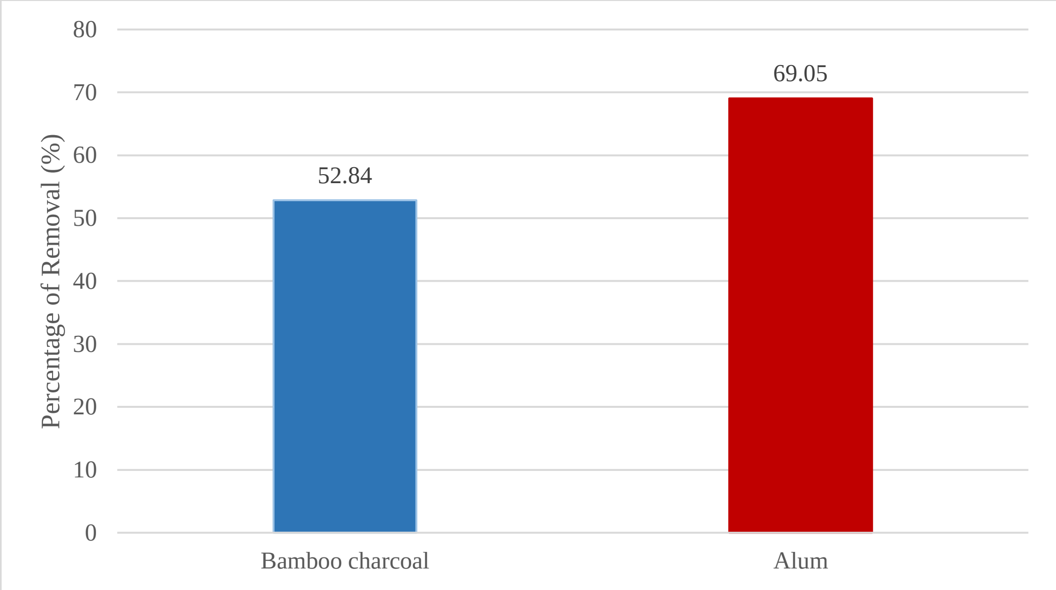

Figure 5: COD removal by using the optimum dosage and pH of coagulants

Before treating the wastewater with coagulants, the initial total suspended solids obtained is 183 mg/L. After running the jar test, total suspended solid data was tabulated using the optimum dosage of coagulants, optimum pH, and optimum mixing speed of bamboo charcoal and alum. The graph in Figure 6 demonstrates the result obtained on the total suspended solids in this study. The trend of the graph is rising. The combination of bamboo charcoal and alum coagulant obtained the highest removal of the total suspended solids which is 66.18 % with the total suspended solids 62 mg/L. While the total suspended solids for bamboo charcoal coagulant with 94 mg/L obtained higher than the alum coagulant with 70 mg/L. The removal of the total suspended solids for both coagulants were 48.73 % and 61.82 %, respectively.

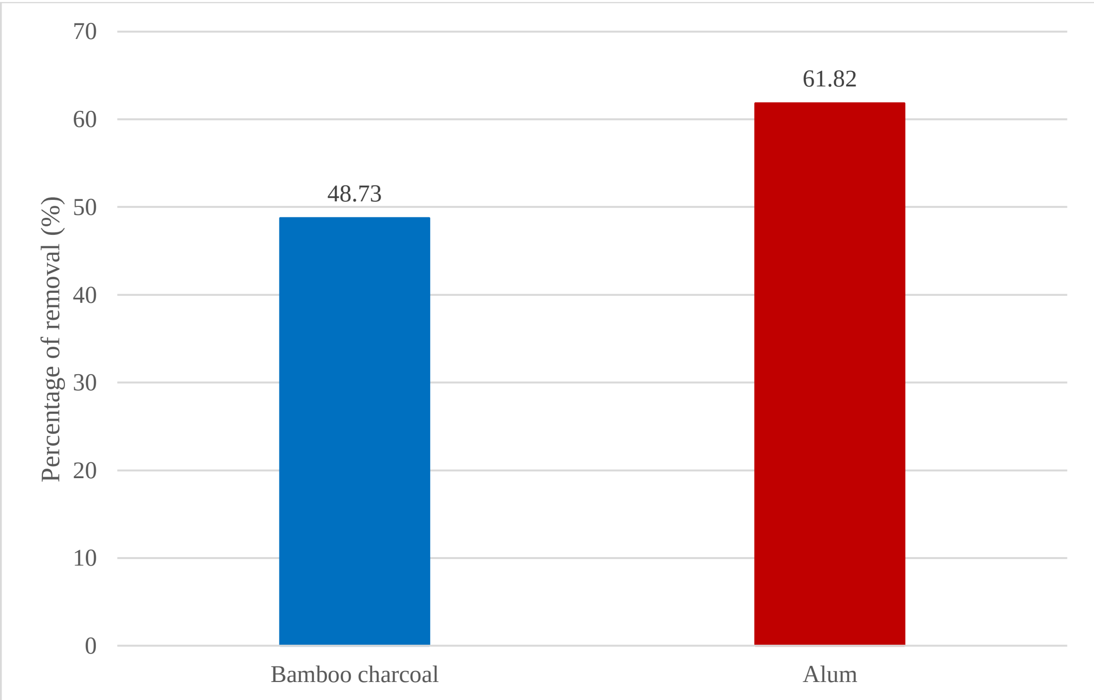

Figure 6: TSS removal by using the optimum dosage and pH of coagulants

Next, the initial dissolved oxygen of wastewater is 6.52 mg/L. After run jar test, the result of dissolved oxygen removal was observed by using the optimum coagulant dosage and optimum pH of the bamboo charcoal and alum coagulants. Therefore, the dissolved oxygen dropped. However, the bamboo charcoal coagulant shown the lowest dissolved oxygen since it dropped from 6.52 mg/L to 3.25 mg/L. While the alum coagulant able to drop the dissolved oxygen from 6.52 mg/L to 1.20 mg/L.

3.5 Comparison of both coagulants' performance on parameters with Malaysia Water Quality Index

The comparison of each parameter when the wastewater is treated with bamboo charcoal and alum coagulant was done to examine the effectiveness of each coagulant in treating wastewater. Table 3 tabulated all the results obtained. From the table below, the coagulants shown the potential in treating wastewater although cannot reach the of Malaysia Water Quality Index.

Table 3: Comparison of both coagulants and Malaysia Quality Index

Parameter	Raw wastewater	Wastewater Treatment				Malaysia Water Quality Index
		Bamboo Charcoal		Alum		
		Optimum Dosage (30 mg/L)	Optimum pH	Optimum Dosage (30 mg/L)	Optimum pH	
pH	8.6	6	8	6	8	5-9
Turbidity	127 NTU	30.26 NTU		13.37 NTU		-
COD	475 mg/L	224 mg/L		147 mg/L		50-100 mg/L
TSS	183 mg/L	94 mg/L		70 mg/L		150-300mg/L
DO	6.52 mg/L	3.25 mg/L		1.2 mg/L		1-3 mg/L

4. Conclusion

The characterisation of bamboo charcoal coagulant was identified by using Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscope (SEM), and Energy Dispersive X-ray (EDX). The surface morphology of the particles looks like a honeycomb. The bamboo charcoal covered in numerous minuscule holes, which make its structure highly porous. Few parameters were carried out such as pH, dissolved oxygen (DO), chemical oxygen demand (COD) and total suspended solids (TSS). Both coagulants used in this study show the potential to treat turbidity wastewater. The dosage of coagulant used influenced the performance of the coagulant in wastewater treatment by insufficient dosage or overdosing. The optimum dosage of bamboo charcoal and alum were 30 mg/L. For the optimum pH is at pH 8 where the alum coagulant recorded the highest percentage of removal which was 88.29 % while bamboo charcoal recorded by 73.73 %. Lastly, the Malaysia Water Quality Index compared bamboo charcoal and alum coagulant performances. The wastewater categorised in class IV of Malaysia Water Quality Index. All coagulants tested reduced all the tested parameters considerably. Although bamboo charcoal at varying ratios did not meet most water quality index standards, it shows the high potential in treating the wastewater. The alum coagulant contributed to excellent turbidity removal compared to the bamboo charcoal. However, this study achieved the objectives stated after treating the wastewater with the natural and artificial coagulants, although below the permissible limit prescribed by the Environment Quality Act.

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