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HIGH TURBIDITY AND COD REMOVAL IN RIVER WATER USING LOW DOSAGE PLANT-BASED TACCA LEONTOPETALOIDES FLOCCULANT (TBPF) FOLLOWED BY ACTIVATED CARBON TREATMENT

Juferi Idris[a,b*], Bryan Donovan Jonius[a], Fergie Rikan Lius[a], Nurul Shuhada Mohd Makhtar[b], Rafidah Husen[c]

[a]School of Chemical Engineering, College of Engineering, Universiti Teknologi MARA (UiTM), Sarawak Branch, Samarahan Campus, 94300 Kota Samarahan, Sarawak, Malaysia
[b]School of Chemical Engineering, College of Engineering, Universiti Teknologi MARA (UiTM), Selangor Branch, 40450, Shah Alam, Selangor, Malaysia
[c]Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), Sarawak Branch, Samarahan 2 Campus, 94300, Kota Samarahan, Sarawak, Malaysia

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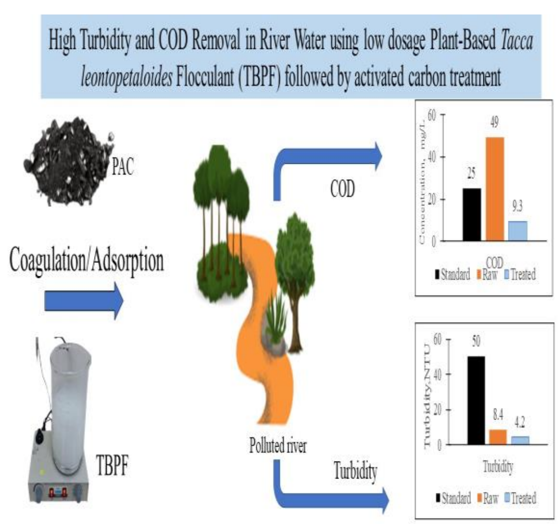
*Corresponding author
juferi@uitm.edu.my

Graphical abstract



Abstract

Pollution in river water affects human, plant and animal health and activities, and its removal using chemical coagulants is a huge concern. This study aims to reduce turbidity and COD pollutants in river water through coagulation-adsorption process by using Tacca leontopetaloides biopolymer flocculant (TBPF) and powder activated carbon (PAC). In coagulation experiment, TBPF dosages were varied to evaluate the effect on turbidity and COD removal in river water by using Bioblock flocculator followed by adsorption process by adding PAC. The results found that at 200 mg/L of TBPF dosage with 2000 mg/L of PAC, the maximum turbidity and COD removal were obtained at 49% and 81%, respectively. The final turbidity and COD loads were 4.2 NTU and 9.3 mg/L, respectively, which were below the standard limit set for CLASS IIB provided by the National Water Quality Standards of Malaysia (NWQSM). High turbidity and COD removal using low dosage of environmental friendly plant-based TBPF-PAC through coagulation-adsorption process in this study has a great potential for river water treatment, particularly at the domestic area.

Keywords: River water, coagulation-adsorption, natural flocculant, Tacca leontopetaloides biopolymer flocculant (TBPF), powder activated carbon (PAC)

Abstrak

Pencemaran air sungai memberi kesan buruk kepada kesihatan dan aktiviti manusia, tumbuh-tumbuhan dan haiwan, dan merawatnya menggunakan penggumpal kimia adalah sesuatu yang membimbangkan Tujuan kajian ini adalah untuk menurunkan kadar pencemaran 'turbidity' dan 'COD' di dalam air sungai melalui penggumpalan dan penyerapan proses dengan menggunakan

'Tacca leontopetaloides biopolymer flocculant (TBPF)'dan 'powder activated carbon (PAC)'. Di dalam penggumpalan eksperimen, TBPF dos di pelbagaikan untuk menguji kesan kepada penurunan 'turbidity' dan 'COD' di dalam air sungai dengan menggunakan 'Bioblock flocculator' diikuti dengan PAC untuk penyerapan proses Keputusan menunjukkan 200 mg/L dos TBPF dan 2000 mg/L PAC, kadar penurunan 'turbidty' dan 'COD' pada tahap maksima iaitu masing-masing 49% dan 81%. Bacaan akhir 'turbidty' dan 'COD' adalah rendah berbanding dengan standard kualiti air kebangsaan Malaysia (NWQSM). Maksimum penurunan 'turbidity' dan 'COD' dengan menggunakan dos yang sedikit dari TBPF-PAC berasaskan tumbuhan yang mesra alam melalui proses penyerapan penggumpalan proses di dalam kajian ini, menunjukkan ia sangat berpotensi digunakan untuk rawatan air sungai terutama di kawasan dalam negeri.

Kata kunci: Air sungai, gumpalan-penyerapan, penggumpal semulajadi, *Tacca leontopetaloides biopolymer flocculant* (TBPF), *powder activated carbon* (PAC)

1.0 INTRODUCTION

Surface water, which covers approximately 75% of the earth's surface, is representing of our oceans, lakes, rivers, and all of the other blue spots on the world map. It is important resources for every life on the earth. In Malaysia, about 98% of the total water used originates from the rivers and 70% of the water resources in the country are for agriculture industry [1]. According to the most recent Updates of Water Environment Governance in Malaysia reported by Ying [2], 50 out of 638 rivers were identified as polluted, 231 out of 638 rivers were identified as slightly polluted and the rest are clean. The main reported pollutant load in 2018 were contributed by the manufacturing industries, agriculture-based industries, wet market, sewage treatment plant and piggery activities [3]. Water quality has now become a severe issue that requires immediate response. Due to the high cost of polluted water treatment process, good quality water has become a luxury item.

Polluted river water must be treated before it may be distributed to consumers for home consumption. Appropriate technology is required to ensure that dirty river water can be treated, resulting in safe drinking water. Common technologies available to treat polluted water are biological and physical-chemical treatment. Biological treatment techniques have the disadvantages of requiring a huge amount of space, costly maintenance, and a long retention time for operating the process [4]. As a result, physical–chemical treatment has been proposed and practiced for a lengthy period of time. The coagulation–flocculation technique is the most successful method of treating wastewater utilizing physical–chemical treatment [5]. In coagulation, a chemical coagulant is added to enhance the agglomeration of colloid particles in the suspension water to form larger flocs and end up settling gravitationally [6]. In some cases, flocculant is added to further bridging the floc particles so that the particles are heavily dense and quickly accelerate through gravity. Currently, chemical coagulants such as Alum and Ferric based salt are used by industries and have claimed a drawback for long-term effects [7]. Additionally, the majority of synthetic chemical polymers are derived from petroleum-based basic ingredients and processed in ways that are not always environmentally friendly or safe [8]. Therefore, plant-based coagulant/flocculant is extensively important.

In the recent years, natural coagulants from agriculture based namely tannin, gum, cellulose and starch are introduced [10–13]. In a previous study, Tacca leontopetaloides starch (TBPF) is used as flocculant in leachate pollutants removal. At pH 3 of leachate and 240 mg/L of TBPF dosage, 75–79%, 90.7–91%, 14–25%, and 93–94% of turbidity, (total suspended solid) TSS, (chemical oxygen demand) COD and Color, respectively were removed [13]. TBPF is primarily made of alpha–D– (+) glucopyranose monosaccharide and D–glucopyranosyl residues linked together by a $(1 \rightarrow 4)$ and a $(1 \rightarrow 6)$ bonds. polysaccharides. The amylose/amylopectin polymer mixture, viscosity, and zeta potential of TBPF are reported to be 26:74, 0.037–0.04 Pa·s, and -13.14 mV, respectively [13], which helps in the flocculation.

Removal of pollutants using combination treatment via coagulation-adsorption has been proven to meet the standard limit set by the authorities. The combination of biological and coagulation treatment on leachate has been used by Yong *et al*. [15], where a sequential treatment via sequencing batch reactor (SBR) followed by coagulation was used to treat TSS, COD, ammoniacal nitrogen (NH3-N), and color from raw landfill leachate as a results, 91.82% TSS, 84.89% COD, 94.25% NH3-N, and 85.81% color are obtained after two-step sequential treatment. This combination method also able to remove 100% selenium, 87.2%

barium, 95% cadmium, 95% lead, 95.3% copper, 62.9% iron, 50% silver, 41.3% nickel, 41.2% zinc, 34.8% arsenic, and 22.9% manganese. Shadi *et al*. [16] reported using a combination of adsorption and electro-flotation process to remove color, turbidity, NH3-N, total dissolved solid (TDS) and COD in leachate. A Fe2O3 nanoparticles adsorbents and electro-flotation technology have been implemented and, as a result, 100% color, 9% turbidity, 99% NH3–N, 99% TDS, and 96% COD in landfill leachate were removed. The removal efficiency of combination process cannot be argued, however, studies using combination of coagulation-adsorption process using natural coagulants/flocculant followed by adsorbent for river water treatment are still limited. Therefore, this paper aims to evaluate the performance of coagulation-adsorption process by using natural plant based Tacca leontopetaloides biopolymer flocculant and powder activated carbon on turbidity and COD removal in river water.

2.0 METHODOLOGY

Powder Activated Carbon (PAC)

Powder activated carbon (PAC) was supplied by Merck, Germany with approximately 1000 m^2/g of surface area.

Tacca leontopetaloides Biopolymer Flocculant (TBPF) Collection and Preparation

Tacca leontopetaloides plant was obtained from Mersing, Johor, Malaysia. Tacca powder was prepared by (drying and grinding). Tacca leontopetaloides biopolymer flocculant (TBPF) was prepared fresh according to Mohd Makhtar *et al*. [14] with some modification. 20 g of Tacca powder were dissolved in 1000 mL of 80°C distilled water. The pH of TBPF was adjusted to pH 3 by using 1.0 M HCl. The process flow of this work is showed in Figure 1.

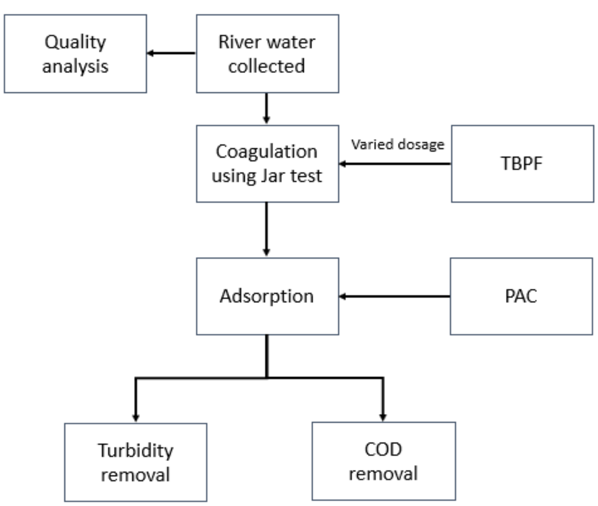


Figure 1 Process flow diagram

River Water Sampling and Characterization

River water samples were collected from Sg. Bedil Kecil situated at coordinates 1^0 34'12''N 110'20'35''E in Kuching Sarawak (Figure 2).

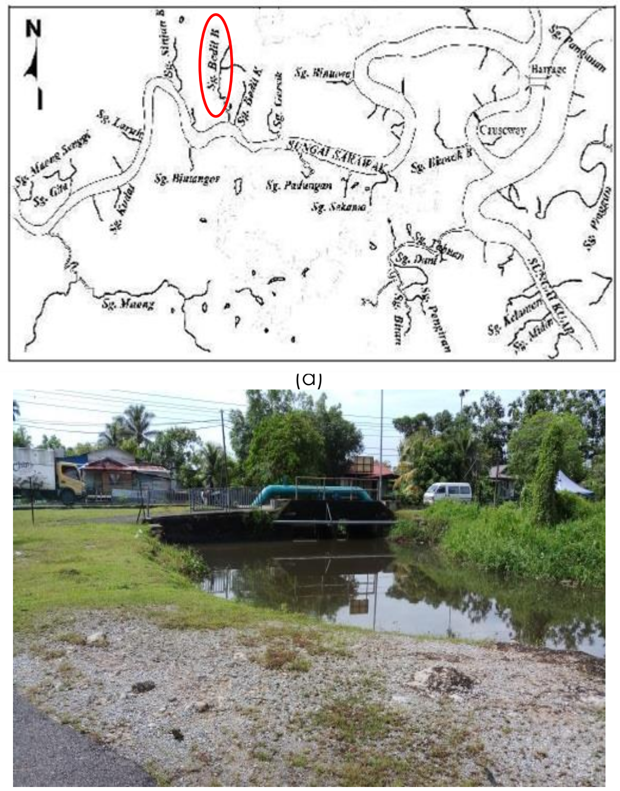


Figure 2 (a)Map of Sg. Bedil Kecil [18] and (b) Water Sampling point of Sg Bedil

The samples were taken at several points early in the morning around 0600hrs-0700hrs. The river water sampling was based on Guidelines for Drinking-water Quality under water sampling and examination section [16]. Water samples were poured into 1.5L sealed-cap polyethylene plastic bottles and stored in refrigerator at 4 ^{0}C to minimize chemical and biological reaction before being used for characterization and experimental purposes. Firstly, pH and turbidity of the river water were determined by using METTLER TOLEDO pH meter and portable turbidity meter (HI93703) HANNA INSTRUMENT, respectively. HACH Digital Reactor Block 200 (HACH, Loveland, Calorado, USA) was used to determine COD by following United States Environmental Protection Agency (USEPA) method guideline. The rest of the water quality measurements including dissolved oxygen (DO), total suspended solid (TSS), biological oxygen demand (BOD), color, salinity, total hardness, ammoniacal nitrogen, heavy metal, and chloride followed Standard Method of Water and Wastewater [17]. All analysis was performed in duplicates.

Coagulation-Adsorption Experiment

Experiments were performed at room temperature using a six-paddle rotor (24.5 mm x 63.5 mm) Bioblock flocculator with a 1L beaker. 500 mL river water was transferred into 4 beakers without pH adjustment (river water at pH 7.5). The desired amount of TBPF dosage (200-800 mg/L) was added to the water and mixed at 100 rpm for 45 min to keep the particulates uniformly suspended. The mixture was left for 1 h, and then used in adsorption experiment using PAC. 2000 mg/L of PAC was added into each of the suspension (river water treated with TBPF) and stirred manually for 10 sec. The suspension was left overnight to ensure that the flocs settled down through gravity settlement. Then, the supernatant was collected 5 cm from the surface of treated water and filtered with Waltman filter paper No.2 (110Ø mm). The filtered water was then analyzed for pH, turbidity and COD. The removal of turbidity and COD were calculated using Equation 1. The experiments were repeated in duplicate with different batches experiments to ensure reproducibility of the results.

$$\text{Removal, \%} = (C_i - C_f)/C_i \quad (1)$$

3.0 RESULTS AND DISCUSSION

Raw River Water Characteristics

Table 1 shows the characteristics of the raw river water of Sg. Bedil Kecil.

Table 1 The characteristic of raw river water of Sg. Bedil Kecil

Parameter	Value	National Water Quality class IIB
Temperature, ^{0}C	26.1	-
pH	7.5	6-9
TSS, mg/L	18.0	50
COD, mg/L	49.0	25
Turbidity, NTU	8.4	50
DO, mg/L	1.6	5
BOD, mg/L	688.0	3
Color, Pt-Co	85.0	150
Salinity, mg/L	1.6	-
TDS, mg/L	7.1	-
Aluminum, mg/L	0.4	-
Ammoniacal Nitrogen, mg/L	0.6	0.3
Chloride, mg/L	9.0	200
Total Hardness, mg/L	35.5	250
Iron, mg/L	0.8	1
Magnesium, mg/L	0.9	-
Nitrate Nitrogen, mg/L	0.6	7

The temperature of the water was 26.1 ^{0}C with pH 7.5, contained 18 mg/L of TSS, 7.1 mg/L of TDS, turbidity value of 8.4 NTU, 1.6 mg/L of DO and presented an apparent cloudy color at 85 Pt-CO. The oxygen demand in the river water was high with the COD and BOD values recorded at 49 mg/L and 688 mg/L, respectively. Ammoniacal-nitrogen and nitrate nitrogen were also present with the value of 0.6 mg/L recorded for both. The river water of Sg. Bedil Kecil also showed the presence of chloride, iron, magnesium, and aluminum at 9 mg/L, 0.8 mg/L, 0.9 mg/L, and 0.4 mg/L, respectively, with total hardness recorded at 35.5 mg/L. The water quality of Sg. Bedil Kecil falls under CLASS IIB, which is for recreational use with body contact according to National Water Quality Standards of Malaysia (NWQSM) [19]. Based on this standard, the COD recorded in this study was high compared to the CLASS IIB limit, which requires further treatment. COD is directly related to organic matter in the river, which is directly related to the turbidity of the water [20]. This is mainly due to the direct discharge of pollutants from the residential area into Sg. Bedil Kecil [18]. Since Sg. Bedil Kecil is a tributary of Sg. Sarawak, it will have a long-term impact on the main river's water quality index.

Effect of TBPF Dosage on Coagulation-Adsorption Performance

Turbidity Removal

The performance of the coagulation-adsorption process on the river water based on turbidity removal at different TBPF dosages is shown in Figure 3.

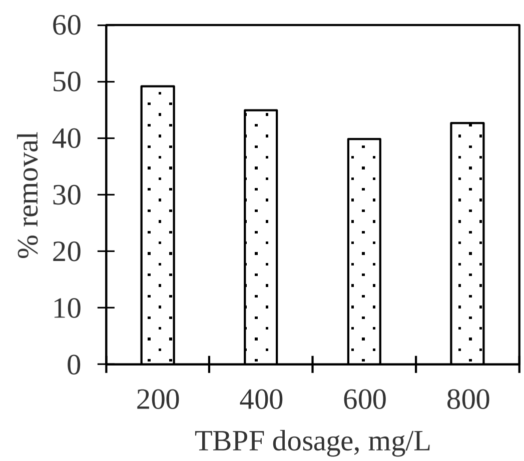


Figure 3 Turbidity Removal at different TBPF Dosage

The highest removal turbidity was observed at 49% using 200 mg/L of TBPF together with a constant PAC dosage. At this dosage, sufficient polymer adsorption sites were provided by TBPF and PAC to be in contact with the colloidal particles in the river water to form particles-polymer-particles aggregates, which in turn led to higher formation of flocs. This is in agreement with Mohd Makhtar *et al.* [14] which studied the effect of TBPF dosage on leachate wastewater. However, increasing the dosage from

200 to 600 mg/L, would stabilize the suspension due to the surface saturation by the excess amount of adsorbed polymer via electrostatic repulsion, resulting in insignificant improvement of organic matter removal which directly records the least amount of turbidity removal [21].

COD Removal

COD is a measure of anerobic degradation of organic matter usually through bacterial activity. The COD value is directly proportional to the amount of organic matter in the river water. Figure 4 shows the effect of TBPF dosage on COD removal in the river water at constant PAC dosage. The highest COD removal of 80% was shown at 200 mg/L of TBPF and due the adsorption of pollutants onto PAC by forming bigger particles size flocs which containing the pollutant-ligands TBPF attached on PAC absorbent. This is in agreement with Li *et al*. [22] stated that PAC provide great reduction in COD level in whatever initial organic matter concentration. COD removal decreased as the TBPF dosage increased. At high TBPF dosage (800 mg/L), the saturated polymer content of TBPF in the suspension contributed to the increase amount of organic matter in the river water, thus reducing the COD removal. Furthermore, Kurniawan *et al*. [23] reported that the use of natural coagulants might lead to an organic load where there is a possibility for undesired and increased microbial activity. Therefore, at the dosage of 200 mg/L, the highest turbidity and COD removal can be obtained through a combination of coagulation-adsorption process.

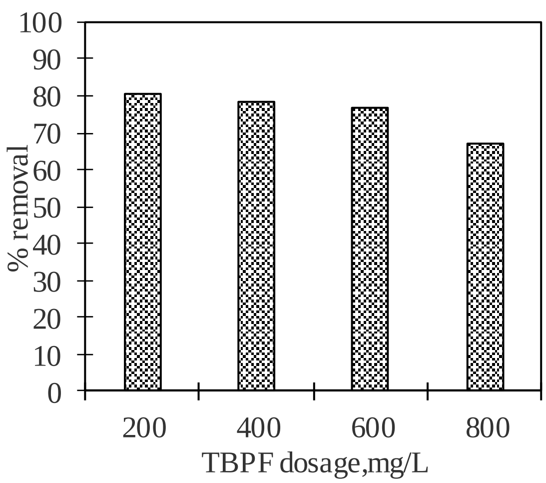


Figure 4 COD Removal at Different TBPF Dosage

Final Treatment and Comparison with Other Studies

Table 2 shows the treated river performance in terms of removal of turbidity and COD using combination of coagulation-adsorption process (TBPF-PAC) as compared with the water quality index by the National Water Quality CLASS IIB. At the optimum TBPF dosage (200 mg/L), turbidity and COD of the final effluent were at 4.2 NTU and 9.3 mg/L, respectively. The treated values reduced greatly compared to the initial values of river water at 8.4 NTU and 49 mg/L of turbidity and COD, respectively. The combination of coagulation-adsorption process is highly efficient to reduce turbidity and COD values to below the standard limit required for CLASS IIB as a recreational use with body contact. The performance of TBPF-PAC combination in coagulation-adsorption process was compared with other studies which applied similar combination process, as shown in Table 3. It is clear that the combination of TBPF-PAC in this study required less amount of coagulant and absorbent dosage compared with the other studies, but nonetheless, still capable of showing comparable performance of COD removal. Moreover, effluent pH of this study was at pH 7 compared with acidic condition at pH5.5 shown by using combination of alum-fly ash and polyferric sulphate-PAC [24–26]. However, the use of natural source of coagulant is more preferable due to its environmental friendly properties. In addition, lower dosage is required to give a comparable effluent removal which can directly reduce the wastewater treatment cost.

Table 2 The characteristic of treated river water using combination coagulation-adsorption process at optimum TBPF dosage

Parameter	Treatment		National Water Quality class IIB
	Before	After	
pH	7.5	7	6-9
Turbidity, NTU	8.4	4.2	50
COD, mg/L	49	9.3	25

Table 3 Comparison studies used combination coagulation-adsorption process

Type of waste water	Coagulant/Flocculant	Absorbent	Effluent pH	Dosage Flocculant, mg/L	Dosage Absorbent, mg/L	% removal	
						Turbidity	COD
River	TBPF	Powder activated carbon (PAC)	7	200	2000	49	81
Leachate[a]	Alum	Fly ash	5.5	600	6000	-	82
Leachate[b]	Polyferric sulphate	Powder activated carbon (PAC)	5.5	300	10000	-	86
POME[c]	FeCl3	AC	8.5	900	10000	-	91

a [24]);b [25] c [26]

4.0 CONCLUSION

The turbidity and COD removal in Sg. Bedil Kecil via a combination of TBPF-PAC in the coagulation-adsorption process has been successfully evaluated. The combination of TBPF-PAC was able to remove 49% and 81% of turbidity and COD, respectively, at 200 mg/L of TBPF and constant PAC dosage. At this removal performance, the turbidity and COD (4.2 NTU and 9.3 mg/L respectively) of the effluent discharged was below the standard limit set for CLASS IIB. Moreover, the performance of turbidity and COD removal using TBPF-PAC in this study was comparable with existing chemical coagulants. Thus, with the environmentally friendly properties of TBPF, it is recommended to be incorporated in river water treatment.

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