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Textile wastewater treatment using *Moringa oleifera* seeds: optimization via polyacrylamide combination

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Abstract: Moringa oleifera (MO) seeds have a protein with positive charges which act as cationic polyelectrolyte and active substances; rhamnosyloxy benzyl isothiocyanate. These substances are useful to reduce and adsorb pollutants and dyes in textile wastewaters. However, the use of MO seeds as a coagulant is inadequate to improve the wastewater quality. Therefore, in this study, the coagulation performance was improved by the addition of anionic polyarcylamide (PAM). Results revealed that the combination of MO+PAM showed a better performance than MO only. The removal efficiency of wastewater parameters was enhanced to 88.83%, 80.58%, 19.90%, and 5.86% for dye, TSS, BOD, and COD, respectively. The addition of PAM in MO coagulant also assisted in reducing the settling time significantly (30 min). Furthermore, SEM images proved that dye solid and MO seeds combine to create clumps or flocs. Then, dye substances were drawn or trapped by the porous nature of the charge-containing MO seeds. As a whole, the use of MO+PAM gives a new notion in treating textile wastewater quality.
Keywords: coagulant, dyes, Moringa oleifera, polyacrylamide, wastewater.

1. Introduction

Textile industries usually use dyes in their production process. It is applied for several activities such as washing, printing, dyeing, and finishing, which they are majorly contribute for producing colored effluents. A previous study by [1] stated that around 280,000 tons of dyes are emitted as wastewaters into the environment by textile manufactures. Furthermore, the pollution of clean water with dyes can affect human health because they are carcinogenic, toxic, teratogenic, and mutagenic [2]. Colored wastewaters affect the environment as emitted into waterbodies by hindering sunlight penetration and reducing dissolved oxygen supply in water [3]. In addition, the chlorophyll content of water plants reduces with textile wastewater in the water, which causes to decrease in protein and carbohydrate of plants [4].

According to previous studies, the coagulation method can be significantly effective in improving textile wastewater quality [5][6]. This method has several benefits, like low cost, simplicity, and fast process [7]. Some studies have highlighted that the use of coagulants and coagulant aids have notable effect on the removal of pollutants in the wastewater via coagulation [8]. The most widely used coagulants are aluminium and iron salt, that lead to environmental toxicity [9]. For instance, aluminium can contribute to carcinogenic and neurotoxic effects on human health [10]. Thus, it is needed to use natural coagulants or coagulant aids and examine their coagulant mechanism and potency for the removal of pollutants in the wastewater.

This current study was concerned with the removal of dye (Direct Red 23), TSS, BOD, and COD, which are generally analyzed when conducting the textile wastewater treatment. Based on our literature study, there are limited studies about the removal of Direct Red 23 dye. In this study, Moringa oleifera (MO) seeds as a biocoagulant and anionic polyacrylamide (PAM) as a coagulant aid were used. Moringa seeds possess water-soluble proteins that, upon dissolution in water, engage with and neutralise the negative charges of suspended particles such as dirt and clay. PAM's extensive chains can intertwine and connect dispersed particles, aggregating them into bigger clusters. The Moringa oleifera plants are widely distributed in all parts of the world and come from the Moringacea family. The MO seeds can be a promising cheap coagulant for eliminating pollutants from the wastewater. Because the MO is available in Indonesia, utilizing it as a coagulant in the textile manufacturing may be cost-effective. Previous studies have reported that MO seeds are effective as coagulant in wastewater treatment [11][12]. But the combination of MO seeds with PAM has not been investigated further. Thus, this current study tried to assess the effect of MO seeds and PAM on the removal of pollutants in the textile wastewater. The aims of this study were to examine the effectiveness of two types of coagulation process; MO and MO+PAM in eliminating pollutants, analyze the behind of mechanism from the coagulation process, and investigate the settling time that affect the removal efficiency of the wastewater parameters.

2. Materials and Methods

2.1. Materials

The wastewater used in this study was textile wastewater type, which it emitted from the Jumputan fabric industries in Palembang, South Sumatera Province of Indonesia. The collection process of the wastewater was carried out using a grab sampling technique. Some materials that used in this study like mortar, siever, beaker, jar test, oven, and pH meter. For coagulant, Moringa oleifera seeds and PAM were obtained from the local market in Palembang city. The characteristics of the textile wastewater before treatment are shown in Table 1. It is found that dye, TSS, BOD, and COD were above the national wastewater threshold.

Table 1. The studied wastewater characteristics before treatment.

Parameter	Initial value	Permissible value*
Dye content (Pt.Co)	7,215	200
pH	7.14	6.0-9.0
BOD (mg/l)	125	60
COD (mg/l)	1,425	150
TSS (mg/l)	139	50
Cr^{6+} (mg/l)	<0.011	1.0
$Sulphide^{2-}$ (mg/l)	<0.0006	0.3
Ammonia total (mg/l)	4.3	8.0

Note: *: National wastewater threshold

2.2. Methods

2.2.1. The preparation of biocoagulant

The MO seeds that used in this study were removed from the shells and kernels, and dried in the oven using a temperature of 105°C for one week. Subsequently, the MO seeds were pulverized into a powder by using a mortar and 80 mesh siever.

2.3. Experimental variable and analytical procedures

The jar test was used to apply the coagulation-flocculation process. Total of 200 mL of textile wastewater was mixed with two types of coagulant treatments that are 5 g MO seeds and 5 g MO+0.003 g PAM. While the settling time was arranged to 30, 60, and 90 min. Then, we collected the final supernatant and analyzed the dye, TSS, COD, and BOD. The values after treatment were compared with the initial values before treatment. We carried out all the tests in triplicate to validate the results. We applied the jar test by referring to the IS 3025 (Part 50):2001. The dye content of wastewater was analyzed using a UV/Vis spectrophotometer, the TSS was analyzed using by pH meter. The COD method used SNI 06-6898.2-2019, the Indonesian National Standard for assessing Chemical Oxygen Demand (COD) in water and wastewater by closed reflux spectrophotometry. Moringa seeds possess a water-soluble cationic coagulant protein that aids in diminishing organic matter in water, hence reducing COD and BOD levels. PAM facilitates the aggregation of tiny particles (TSS) in water, hence enhancing their sedimentation or filtration. When organic matter is diminished (due to decreased TSS), the COD is likewise diminished.

2.4. The wastewater parameters analysis

The removal efficiency measurement was carried out based on the standard laboratory using a specific formula as shown in Eq. 1. In addition, the statistical analysis was carried out by the SPSS Statistics version 21 software.

$$\text{Removal efficiency (\%)} = \frac{Co-C1}{Co} \times 100 \qquad \text{(Eq. 1)}$$

where C_0 is the concentration of water variables before treatment and C_1 is the concentration of water variables after the treatment.

3. Results and Discussion

3.1. Effect of settling time on dye content and TSS

In a shorter amount of time (30 minutes), PAM greatly aids in improving dye removal (Figure. 1). The settling time of MO+PAM particles has been greatly decreased. It was decreased from 90 min (without the use of PAM) to 30 min (using PAM). By combining MO and PAM, the high removal efficiency of above 85% can be achieved at the settling time of 30 min.

A study by [13] have found the use of PAM could reduce the settling time from 8 hours to 5 minutes to remove Direct Blue 78 dye in the synthetic wastewater. They obtained the removal efficiency of dye with the value of 94.2%. Furthermore, another study by [14] showed a higher removal efficiency of dye with the value of 99% in the cardboard wastewater. If we compared to our study, the removal efficiency of dye was lower and took a longer settling time. It can be resulted from the different dosage of PAM where in our study, we used less amount of PAM. Several studies have revealed that the PAM can assist in accelerating the flocculation process, which significantly reduces the dye substance in the wastewater [15][16]. This is because PAM speeds up the flocculation process by more effectively binding dye particles, creating larger flocs that enable faster high-value dye removal. There are no appreciable changes in the temporal variation after 30 minutes of PAM use because the dye substances that were already present had already sedimented. The production of larger and more stable flocs reduces the amount of dye particles that are captured during sampling on the top layer of water. There is typically a consistent dye drop when PAM is added. Total of 88.83% of the dye substance was removed in 90 min settling time.

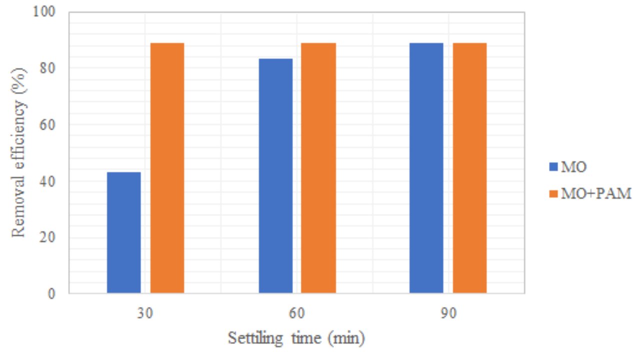

Figure 1. Effect of settling time on the removal efficiency of dye content between MO and MO+PAM coagulants.

Since the drop in TSS is linked to the decrease in dye substance, the decline's trajectory will essentially be the same (Figure. 2). The reason for this is that the more dye particles suspended in the liquid, the more colourant is eliminated in proportion to the amount of suspended solids lost. According to Figure 2, we clearly assume that the use of PAM can significantly increase the removal efficiency of TSS, especially in the early settling time (30 min). There was no significant difference between MO and MO+PAM in the settling time 60 min and 90 min to remove TSS.

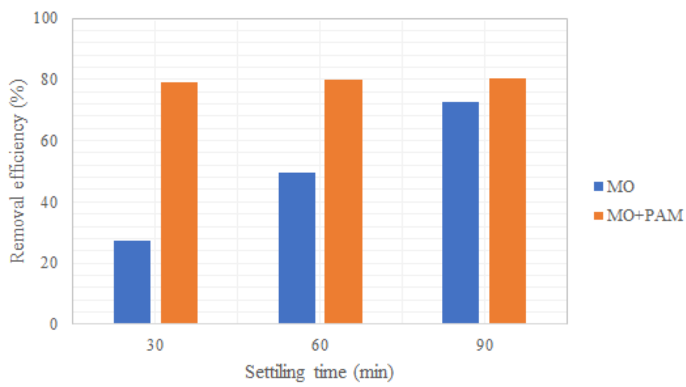

Figure 2. Effect of settling time on the removal efficiency of TSS between MO and MO+PAM coagulants.

3.2. Effect of settling time on COD and BOD

Although PAM showed a less significant effect on BOD and COD reduction, it does give a steady decrease over time (Figure. 3-4).

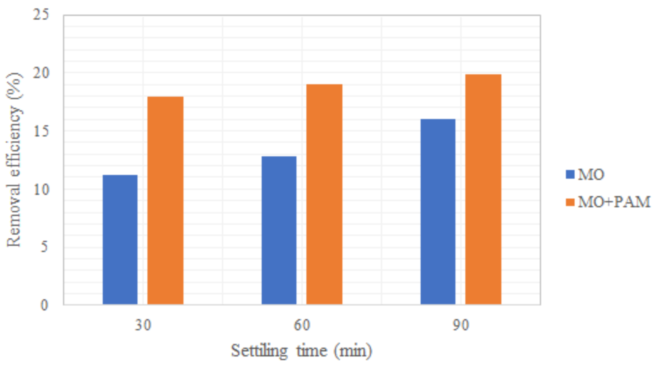

Figure 3. Effect of settling time on the removal efficiency of BOD between MO and MO+PAM coagulants.

PAM has not been able to considerably lower COD and BOD levels in this study yet; it can only speed up the release of dye substances that are difficult to break down. This is due to the fact that the addition of PAM itself is meant to speed up the sedimentation process rather than lower COD and BOD. Controlled microbial activity is essentially the key to reducing COD and BOD. A study by [17] has compared the MO seeds and Tamarin seeds in reducing BOD in the wastewater. Their result revealed that MO seeds showed a better finding in reducing BOD with the value of 72.57% at settling time of 60 min. This reduction is much higher than our study, and also takes a shorter settling time. This is because the longer the settling time is conducted after the coagulation/flocculation mechanism, the higher the reduction of BOD and suspended matter. Interestingly, our study obtained an increase in the removal efficiency of BOD (around 24%) after the addition of PAM at the settling times of 60 and 90 min.

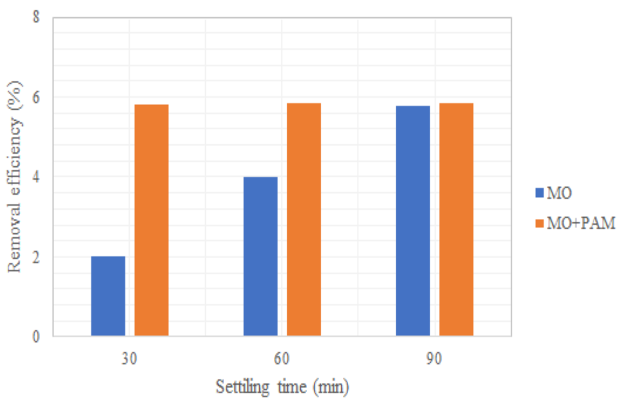

Figure 4. Effect of settling time on the removal efficiency of COD between MO and MO+PAM coagulants.

According to Figure 4, the removal efficiency of BOD and COD increased as the settling time increased. However, the increase in settling time can also contribute to increase pollutants in the wastewater [18].

This is because the MO coagulant attracts the pollutants and settles them at the bottom of the beaker when the settling time is increased.

3.3. SEM analysis

The surface and morphology of the particle structure are visually represented in the MO seeds coagulation process through the use of Scanning Electron Microscopy (SEM) analysis (Figure. 5).

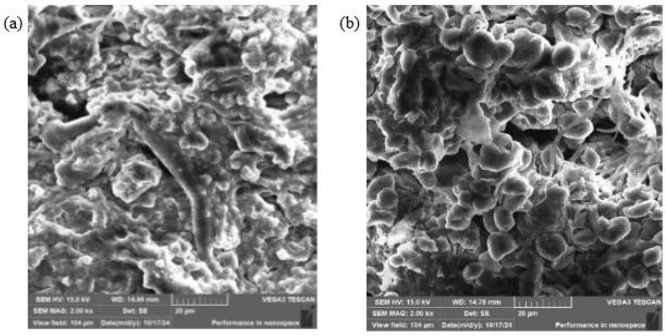

Figure 5. SEM images of MO coagulant before coagulation (a) and after coagulation (b).

The surface of MO seeds may be seen both before and after the coagulation process. This can aid in comprehending the morphological alterations on the particle surface brought about by dyes binding or becoming absorbed. The surface topography of dried MO seeds prior to the coagulation process is depicted in Figure 5a at 2,000× magnification. Based on the SEM analysis, we found the MO coagulant has a rough surface with blocks and irregular shapes. The same findings were also reported by [19][20]. Because of this morphological characteristic, it makes MO is very useful coagulant to eliminate pollutants in wastewater. Furthermore, the morphology of MO seeds following the coagulation process at 2,000× magnification is shown in Figure 5b, where the coagulation process has produced dye solid particles. It is evident from the SEM images that the dye solid and MO seeds combine to create clumps or flocs. Dye substances can be drawn to or trapped by the porous nature of the charge-containing MO seeds. The presence of coagulation and flocculation in this process is demonstrated by the images, which also show that the MO seeds sediment with the dye that is already there and form clumps.

4. Conclusion

It concludes that adding PAM to the coagulation-flocculation process will speed up the generation of floc and increase the rate of settling time; 90 minutes is the ideal duration. This mechanism affects the increase in removal efficiency of dye, TSS, COD, and BOD. However, in this study, we suggest that MO coagulant gives the highest removal efficiency for dye and TSS with more than 75%. The combination of MO and PAM has increased the removal efficiency around 10-25%. The removal efficiency of parameters was in line with the increase of the settling time. Overall, combining these two leads to better waste treatment performance, particularly in improving the textile wastewater quality parameters.

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