Utilization of coconut coir as adsorbent for dye removal in wastewater: The effect of mixing speed

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Abstract. Wastewater from print screen home industry is potential to pollute the environment since it flow into drainage channel without prior treatment and it contains heavy metal ion. The most visible parameter is color due to dye usage. One technology to remove dye is adsorption, and coconut coir is very potential as an adsorbent since its contents of cellulose. This study aims to examine the ability of coconut coir in review of mixing speed and contact time on dye removal in a batch system using Jartest device to adjust the mixing speed. Preparation for making coconut coir adsorbent starts from burning in the furnace and then activated by adding H2SO4 solution. In adsorption process, the 10 gr of activated coconut coir was added into the wastewater and mixed with speed variation of 50 rpm, 100 rpm, 150 rpm, 200 rpm, 250 rpm and contact time variation of 30 minutes, 60 minutes, 90 minutes, 120 minutes and 150 minutes. The results obtained state that coconut coir could remove dye with 99.62% efficiency in only 90 minutes of operation with a stirring speed of 100 rpm. The study proves that activated coconut coir could be an adsorbent for wastewater in textile dyes.

1. Introduction

The screen printing industry produces waste such as liquid waste from the washing process, as well as solid waste produced such as material from fabric waste, and others [1]. Wastes containing pollutants such as screen printing dyes will change the quality of the environment which cannot restore conditions in accordance with the carrying capacity [2]. Therefore in this study utilizing coconut coir waste as the main ingredient in making adsorbents to bind/absorb dyes in screen printing wastewater. Making activated carbon generally involves activation by using chemical solutions in the activation process which can change the texture of the adsorbent that has been activated with a particular chemical solution [3]. The adsorption method is the easiest method to use in reducing color [4]. Coconut coir is chosen as activated carbon because of the large amount of coconut coir waste in the environment which is not widely used [5]. In this study coconut coir waste has the potential as an alternative adsorbent to bind/absorb dyes in household scale screen printing wastewater. The method used in the study of dye reduction is a batch method using Jartest. This is done for an approach to the household-scale screen printing industry.
2. Methodology

2.1. Activation of coconut coir adsorbents
The coconut coir is washed using running water which aims to remove dirt on the coconut husks and dried in the sun for a day to reduce the moisture content that sticks [6]. Then clean and dry coconut husk is oven at 100°C for 15 minutes until charcoal is formed. After that, the coir is smoothed to a uniform size and sieved with a 100 mesh sieve. Charcoal that has been crushed, is put into a desiccator. The carbonized coconut husk was then activated using a 10% concentration of H₂SO₄ for 24 hours. The activated carbon was then washed with distilled water and dried in an oven at 100°C for 15 minutes.

2.2. Determination of optimal activated carbon filling speed
Determination of the speed of stirring activated carbon is done by using variations in the speed of 50, 100, 150, 200, 250 rpm with a time variations of 30, 60, 90, 120 and 150 minutes. The beaker is filled with 250 ml of screen printing wastewater. In the adsorption process, 10 grams of coconut coir are added to the wastewater and added using Jartest. The next step is to separate residues using filtrate. The filtrate was obtained by using a spectrophotometer with a wavelength of 450 nm so that the optimal stirring speed was obtained.

2.3. Removal efficiency and adsorption capacity analysis
The contact between solid and liquid phases can be known using the adsorption isotherm. Conversation between the two adsorption phases can be determined using the Langmuir and Freundlich methods which are agreed in equality (1) and (2) [7]:

\[
\frac{C_e}{q_e} = \frac{C_e}{q_m} + \frac{1}{q_m K_l} \tag{1}
\]

\[
\ln q_e = \ln K_f + \frac{1}{n} \times (\ln C_e) \tag{2}
\]

Where \(q_e\) is the amount of dye absorbed (mg / g), \(C_e\) is dye concentration and equilibrium (mg / L), \(q_m\) is maximum adsorption capacity of adsorbent (mg.g⁻¹), \(K_l\) is Langmuir isotherm constant, \(K_f\) is Freundlich isotherm constant (L / mg), and \(n\) is heterogeneity factor which shows the capacity and intensity of adsorption. Reactions that depend only on one substance or are proportional to one of the reactants are called first-order reactions. First order linear equation shown in equation (3) and second order linear equation shown in equation (4) as follows [8].

\[
\ln = \left( q_e - q_t \right) = \ln q_e - Kl \cdot t \tag{3}
\]

\[
\frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \frac{t}{q_e} \tag{4}
\]

Where \(q_e\) is the number of metal ions absorbed at equilibrium (mg/g), \(q_t\) is the number of metal ions absorbed at time \(t\) (mg/g), \(t\) is time (minutes), \(K_1\) is the rate constant of constants (minutes⁻¹), \(K_2\) is the rate constant of constants (g.mg⁻¹.minute⁻¹).

3. Results and discussion

3.1. Color analysis of household screen printing waste water
Dyestuffs cause much damage to the environment if released without proper and safe handling. Waste dyes are difficult to decompose, are resistant, non-biodegradable, and toxic organic compounds [9]. All liquid discharges originating from the results of the process of producing clothes with screen printing dyes which are no longer used are called industrial liquid waste [10].
Table 1. Characterization of screen printing wastewater.

| Sample        | Content |
|---------------|---------|
| Green Color   | 173.32  |
| Blue Color    | 164.18  |
| White Color   | 135.06  |
| Yellow Color  | 130.21  |
| Black Color   | 112.66  |
| Red Color     | 18.82   |

The results of the color analysis of screen printing household wastewater, which is located in the Krendang Timur Kelurahan area, Tambora, West Jakarta. After looking at each sample, the highest levels were found in green at 173.32 and the lowest was in red at 18.82. The following results from the characterization of screen printing wastewater can be seen in Table 1.

3.2. Isotherm adsorption

Langmur isothermal adsorption can be assumed as the adsorption rate which will depend on the size and structure of the adsorbate molecule, the nature of the solvent and porosity of the adsorbent, the site on the homogeneous surface and the monolayer adsorption. The results of the Langmuir and Freundlich isotherm calculation of the optimal mixing speed of 100 rpm can be seen in Figure 1.

![Figure 1](attachment:figure1.png)

Figure 1. (a) Langmuir Isotherm the optimal mixing speed of 100 rpm and (b) Freundlich Isotherm the optimal mixing speed of 100 rpm.

In Figure 1 shows that the Langmuir isotherm obtains $R^2$ or a regression value of 0.999 while the Freundlich isotherm obtains an $R^2$ of 1. Data can be seen in Table 2.

Table 2. Value of $R^2$ and constants of Langmuir and Freundlich Isotherms.

| Optimum Mixing Speed of 100 Rpm | $R^2$ | Contact | Value  |
|---------------------------------|-------|---------|--------|
| Langmuir                        | 0.9999| a       | 404,610|
|                                 |       | b       | 0.084  |
| Freundlich                      | 1     | Kf      | 36,900 |
|                                 |       | n       | 0.083  |

From the results that can be seen in Table 2, the value of $R^2$ in Langmuir was 0.9999 and Freundlich was 1. The isotherm model related to the value that can be used in staining adsorption was Freundlich. Therefore in the Freundlich isotherm with coconut coir adsorbent, the maximum capacity (Kf) obtained was 36,900 mg/g and the n value was 0.083.
3.3. Adsorption kinetics

A first-order reaction is a reaction whose speed depends on one of the substances that reacts or is proportional to one of the stages of the reactant. Whereas in the second order reaction, a reaction whose speed is directly proportional to the product of the concentration of the two reactants or directly proportional to the square of the concentration of one of the reactants. If the adsorption mechanism that occurs is a second-order reaction where the adsorption velocity that occurs is directly proportional to the two concentrations of followers or one follower the kinetics rate of adsorption of first-order and second-order reactions can be seen in Figure 2.

![Order 1 and Order 2 Kinetics](image)

**Figure 2.** (a) Order 1 on the stirring kinetics of 100 rpm and (b) Order 2 of the stirring kinetics of 100 rpm.

In Figure 2 shows that the kinetics in the first order $R^2$ reaction were 0.5 while in the second order $R^2$ were 1. The results obtained in the figure above can be seen in Table 3.

| Kinetics | $R^2$   | Constant          |
|----------|---------|-------------------|
| Order 1  | 0.5     | 0.014 minutes$^{-1}$ |
| Order 2  | 1       | 291,357 g.mg$^{-1}$ minute$^{-1}$ |

It can be seen in Table 3 results obtained in the table in kinetics of order 1 with $R^2$ of 0.014 minutes$^{-1}$ and kinetics of order 2 with $R^2$ of 291,357 g.mg$^{-1}$ min$^{-1}$. This shows that the stirring speed with an optimal contact time of 60 minutes in the adsorption kinetics was based on the highest linear value, where the higher the linear value, the linearity of the curve based on the linear regression equation of each sequence will be more easily achieved.

3.4. Effect of stirring speed and contact time

In determining the stirring speed and optimum time in this study there are 5 variations of the stirring speed of 50 rpm, 100 rpm, 150 rpm, 200 rpm, 250 rpm and variations of contact time of 30 minutes, 60 minutes, 90 minutes, 120 minutes and 150 minutes aimed at reduce the color content in screen printing household wastewater. The percentage of color removal data obtained with coconut coir adsorbents can be seen in Figure 3.
Figure 3. The correlation of stirring speed with contact time to color removal using coconut coir adsorbents.

It can be seen in Figure 3, the results obtained in the graph show that the optimum stirring speed to absorb the dye is at a stirring speed of 100 rpm with a contact time of 90 minutes with 99.62% administration. This is because at the Jar test with a speed of 100 rpm with a contact time of 90 minutes the adsorbent and adsorbate are spread more evenly so that in this process the adsorption increases.

3.5. Coconut coir waste on a field scale
In this research, The coconut coir obtained from the coconut seller is 6 kg. Making adsorbent from coconut coir requires 5 kg which is still wet and after the carbonization process the coconut coir becomes powder and gets 1.7 kg. This research can be carried out on a field scale if a screen printing industry can produce screen printing wastewater as much as 80 liters per day, then:

Coconut Coir Raw Materials Field Scale
Answer:
\[
\text{Coconut Coir Raw Material Field Scale} = \frac{6 \text{ Kg}}{20 \text{ Liters}} \times 80 \text{ Liters} = 24 \text{ Kg}
\]

Laboratory Scale Coconut Coir Adsorbent Doses
\[
\text{Laboratory Scale Coco Adsorbent Dose} = \frac{1.7 \text{ Kg}}{20 \text{ Liters}} \times 80 \text{ Liters} = 6.8 \text{ Kg}
\]

So, in this study the raw material for field-scale coconut coir is as much as 24 kg in its use in the screen printing industry and the dose of laboratory coconut coir adsorbent is 6.8 kg. The amount of coconut coir waste in 2020 is 18 million tons, the utilization of coconut coir is still less than 5% whereas the amount of coconut coir production is abundant and the characteristics of coconut coir have the potential as a useful alternative [11]. In applying the use of coconut coir waste as an adsorbent. In this study, it can help reduce coconut coir waste in an environment that is still rarely utilized so that it causes accumulation of coconut coir waste.

4. Conclusions
Based on an analysis of the screen printing industry located in Krendang Timur, Gang 6, West Jakarta, household-scale screen printing wastewater shows that green dyes possess the highest color content. In
the study using 5 variations for stirring speed and contact time. The results show that carbon active coconut coir is very good in adsorbing colors with 99.62% allowance in only 90 minutes contact time with a stirring speed of 100 rpm. This is because at the stirring speed of 100 rpm the process of distributing the adsorbent is evenly distributed between the adsorbent and the adsorbate, so that this coconut coir adsorbent has the potential to be effective in reducing the color content in the screen printing wastewater sample. In this study, the raw material for coconut husk on a field scale of 6 kg was then processed through an oven with a temperature of 100°C for 15 minutes to 1,717 grams (1.7 Kg) and after the sifting process with a 100 mesh sieve to 1,454 grams (1.4 Kg) activated adsorbents were 106,147 grams (0.106 kg) for screen printing waste water as much as 20 L. In the application of the use of raw materials for field scale coconut coir as much as 24 kg in its use in the screen printing industry and the dose of laboratory coir adsorbents as much as 6.8 kg. With this research, we can utilize coconut coir waste to reduce coconut coir waste which is rarely used and does not require a large cost in the manufacture of activated carbon coconut coir.

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