Adsorption of methylene blue dye onto activated carbon prepared from sugarcane leaves by Langmuir and Freundlich isotherm

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Abstract

Activated carbon is highly effective adsorbent for removing organic contaminants due to its high surface area and large pores, but commercial activated carbon is expensive. Therefore, much attention is on the preparation of carbon from agricultural waste. The main objective of this study was to adsorb methylene blue dye by activated carbon prepared from sugarcane leaves. In the experiment, activated carbon from sugarcane leaves were stimulated with phosphoric acid and heating up at 400°C for 1 hr. Batch methylene blue adsorption was carried out from initial dye concentration from 100-500 mg/L at 30°C. The experimental data were analyzed by Langmuir and Freundlich isotherms. It was found that the Langmuir isotherm was better fitted and the maximum adsorption capacity was 102.04 mg/g.

Keywords: adsorption, methylene blue, activated carbon, sugarcane leaves

Introduction

Dyes are used for dying products and they are lost in dye effluent during such dying process. The presence of dyes can cause water pollution. Several treatments have been used for the removal of dyes from aqueous solutions. Among several dye removal techniques, adsorption is an efficient one to remove different kinds of dyes from water and wastewater. Activated carbon is the most efficient adsorbent because of high surface area but it is relatively high price. Therefore, much attention is on the preparation of carbon from agricultural waste for ultimate use as adsorbents (Basar, 2006; El–Sayed, et al., 2014).

Sugarcane leaves left in the fields during sugarcane harvesting are burnt, which produces fly ash, severely damages soil microbial diversity and raises environmental concerns. For this work, sugarcane leaves were used to prepare activated carbon and applied for methylene blue adsorption in aqueous solution. The effect of adsorbents such as contact time and initial dye concentration were investigated. The equilibrium adsorption data were analyzed by Langmuir and Freundlich isotherm models.

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Materials and Methods

Preparation of adsorbent

Sugarcane leaves were obtained from Khok Samrong District, Lopburi, Thailand. It was washed several times with tap water and dried in a hot air oven. Then, sugarcane leaves were cut to about 1 inch and soak in 1.0 M phosphoric acid with the ratio of 1:10 (g/ml) for 2 hr. It was dried at temperature 120ºC for 24 hr. The char of sugarcane bagasse was heated up to activation temperature at 400ºC for 1 hr. After that, it was rinsed with distilled water until its pH value was 7 and it was dried at 80ºC for 24 hr. The activated carbon was crushed with blender and sieved to 150–300 μm. Then, it was stored in a desiccator until used.

Characterization of adsorbent

The surface morphology of adsorbent was studied by scanning electron microscope (SEM).

Preparation of adsorbate

Methylene blue (C.l. 52015, Molecular Formula C_{16}H_{18}N_{3}S Cl, molecular weight = 319.86 g/mol) was used as an adsorbate in this study. It was supplied by Merck, Germany.

Adsorption Study

In each adsorption experiment, 100 ml of methylene blue concentration (100–500 mg/L) solution was added to 0.4 g of activated carbon in 250-ml Erlenmeyer flask. The flasks of mixture were stirred at 200 rpm in an isothermal shaker (30ºC) at equilibrium time of 210 min. The effect of adsorption at the varying time (5-360 min) was studied previously (not shown). At equilibrium time, each sample was filtered and the methylene blue concentration remaining in solution was measured by a double beam UV– Visible spectrophotometer at 662 nm. The adsorption capacity (q_e) was calculated as follows:

\[ q_e = \frac{(C_o - C_e) V}{W} \]  

where \( C_o \) and \( C_e \) (mg/L) were dye concentrations at initial and equilibrium, \( V(L) \) was the volume of the solution, \( q_e \) (mg/g) was the amount dye adsorbed at equilibrium time (min), and \( W(g) \) is the mass of adsorbent.

Adsorption Isotherm

Experimental isotherms are useful for describing adsorption capacity. The Langmuir and Freundlich are used to represent the data of adsorption. The Langmuir isotherm in linear form is represented as follows:

\[ \frac{C_o}{q_e} = \frac{1}{q_m} + \frac{1}{K_L q_m} \]  

where \( K_L \) is the Langmuir constant and \( q_m \) (mg/g) is the maximum adsorption capacity.

The essential characteristics of the Langmuir isotherm can be expressed in terms of a dimensionless separation factor or equilibrium parameter \( (R_L) \) which is defined by

\[ R_L = \frac{1}{1 + K_L C_o} \]

The Freundlich isotherm in linear form is represented as follows:

\[ \log q_e = \log K_F + \frac{1}{n} \log C_e \]

where \( K_F \) (L/g) is the adsorption capacity and \( 1/n \) is the adsorption intensity.

Results*

Characterization of adsorbent by SEM

Figure 1 showed the SEM of activated carbon (before adsorption). It was seen that activated carbons obtained from sugarcane leaves had rougher and porous surface with random widely distributed crevasses.
Adsorption isotherm

For isotherm study, the batch adsorption was carried out from different initial methylene blue concentration (100–500 mg/L) at equilibrium time (210 min). From Fig 2, the results showed that the adsorption capacity increased (20.44, 46.25, 62.74, 92.23 and 100.37 mg/g) with the increase of initial methylene blue concentration (100, 200, 300, 400 and 500 mg/L). The equilibrium experimental data were analyzed using linear Langmuir and Freundlich isotherms. The calculated parameters and corresponding regression coefficient ($R^2$) values were shown in Table 1. Based on the regression coefficient, the data were better fitted by the Langmuir (0.94) than the Freundlich isotherm (0.74).

Discussions*

In this study, the adsorption of methylene blue onto activated carbon prepared from sugarcane leaf wastes was investigated. Activated carbon is commonly prepared by two methods: physical and chemical activations. $\text{H}_3\text{PO}_4$ is the most widely used impregnation agent (Yakout and El-Deen, 2016). It is a suitable activating agent for the preparation of high porosity carbon. For the adsorption study, the results showed that the adsorption capacity increased with the increase of initial methylene blue concentration. This is due to the fact that with increased dye concentration, the driving force for mass transfer also increases (Pathania et al., 2017). For isotherm study, the equilibrium experimental data were fitted well with the Langmuir model. This indicated the monolayer coverage of the adsorbate on the surface of the adsorbent. The values of $0<0.1\text{L}<1$ (from Langmuir) and $1/n$ (from Freundlich) between 0.1-1.0 indicated the favorable adsorption. In comparison with other carbon adsorbents for methylene blue adsorption, the maximum adsorption capacity ($q_m$) values were shown in Table 2.

Conclusions

In this study, activated carbon was prepared from sugarcane leaves by chemical activation with phosphoric acid and heating up at 400ºC for 1 hr. The methylene blue dye adsorption experiments were studied in the batch process. The equilibrium time of dye adsorption was at 210 min. For adsorption isotherm, the data were better fitted by the Langmuir isotherm and the maximum adsorption capacity was 102.04 mg/g at 30ºC, which confirmed the monolayer sorption of dye molecule on adsorbent surface. The adsorbent showed promising adsorption capacity for methylene blue. The results showed that the activated carbon from sugarcane leaves was effective for the methylene blue dye adsorption.

References


Figure 1. Activated carbon prepared from sugarcane leaves by SEM at 1000X and 2000X

Figure 2. Effect of initial methylene blue concentration onto activated carbon adsorption

Table 1 The isotherm parameters for methylene blue adsorption onto activated carbon

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<th>Freundlich Isotherm</th>
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<td>$K_L$ (L/mg)</td>
<td>$R^2$</td>
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<td>102.04</td>
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Table 2 Adsorption capacities of different activated carbons for methylene blue adsorption

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<th>$q_m$ (mg/g)</th>
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