Valorization of Plants for Water Depollution

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Abstract

The present study concerns the elimination of Eriochrom Black T (EBT) dye, by adsorption onto calcinated potato peels (CPP). This dye is recognized as an organic pollutant because of its high toxicity and possible accumulation in the environment.

The experimentally determined adsorption equilibrium data for EBT was best fitted by the Langmuir isotherm model and the adsorption rate followed a pseudo-second-order kinetics.

Keywords: Adsorption; Eriochrom Black T; Calcinated potato peels; Langmuir isotherm; Pseudo-second order models.

I. Introduction

Ever since the first synthetic dye, Mauveine, first appeared in the market, more and more dyes are being synthesized over the decades. Today there are about hundred thousands types of dyes available and more than seven hundred thousands tons of dyestuff are produced per year to satisfy the needs of industries such as textile, cosmetics, food, paper, etc. [1]. This has inevitably generated a great increase in the amount of dyes being disposed off into wastewater or natural ecosystem, thus resulting in serious pollution of the environment.

Several methods have been developed over the years to remove these toxic dyes from wastewater [2], among which Adsorption has known an important step forward in removing these pollutant species, particularly with the development of new adsorbents from natural, free cost and abundant materials which are competing with granulated or powdered activated carbon [3] which has a major drawback of being highly costly, encouraging the use of low-cost biosorbents as viable alternatives [4].

Consequently the present work focused on the use of low-cost biosorbents, namely peel of potatoes to remove the (EBT). Therefore the adsorption capacity of this biomaterial was tested as calcinated (Calcinated Potato Peels (CPP)).

II. Materials and methods

A. Material

1. Calcinated Carbon

The preparation mode of the adsorbent was quite simple. It consisted of washing the solid support to remove the impurities and placing it in well-capped silica crucibles at 250°C in a furnace for 2h. The product was then powdered and stored in a desiccator ready for use, as shown in Figure 1[5].

![Figure 1. Calcinated adsorbent](image)

<table>
<thead>
<tr>
<th>Type of dye</th>
<th>Anionic azo dye</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular formula</td>
<td>C_{6}H_{12}N_{3}NaO_{5}</td>
</tr>
<tr>
<td>Molecular wt.</td>
<td>461.38 g/mol</td>
</tr>
<tr>
<td>Max. wavelength (λ_{max})</td>
<td>530 nm</td>
</tr>
<tr>
<td>Solubility in water (20°C)</td>
<td>50 g/L</td>
</tr>
<tr>
<td>Solubility in ethanol (20°C)</td>
<td>2 g/L</td>
</tr>
<tr>
<td>Color</td>
<td>Black</td>
</tr>
</tbody>
</table>

Table I. Properties of EBT dye
The characteristics of EBT dye are summarized in Table 1 and its chemical structure is shown in Figure 2 [6].

![Molecular structure of EBT dye](image)

**Figure 2.** Molecular structure of EBT dye

### B. Methods

Adsorption experiments were performed in a batch system, using an initial concentration of 25mg.l\(^{-1}\) at 20\(^\circ\)C, a pH of solution of 6.4, an adsorbent dose of 6g.l\(^{-1}\) and an agitation speed of 500 rpm.

After adsorption, the treated solution was filtered and final dye concentration was analyzed using an UV–vis spectrophotometer where the absorbance characteristics were determined by means of a relationship between the absorbance A and the concentration C as follows:

\[
A = 0.01736C - 0.00234
\]

The samples were collected at predetermined time intervals from 15 to 120 min. The adsorption capacity was calculated using this relation:

\[
q = \frac{(C_o - C)}{m} \times V
\]

with q (mg /g) is the adsorption capacity, C\(_o\) is the initial concentrations of solution of (EBT) (mg.l\(^{-1}\)), V (l) is the volume of solution and m (g) is the weight of the adsorbent.

### III. Results and discussion

#### A. Adsorption kinetic models

The kinetic study is helpful in the prediction of the adsorption rate and provides important information for designing and modeling the processes.

Adsorption kinetics was modeled by the pseudo first and second -orders rate equations. Linear plots of the two considered kinetic models and the adsorption kinetic rate constants are shown in Figures 3 and 4 and Table.2, respectively. Pseudo second-order model shows a good correlation values.

The pseudo-first-order kinetic model was given by Langen and Svenska (Langen and Svenska, (1898)) and has been widely used to predict the adsorption kinetics [7]. It can be expressed in a linear form as follows:

\[
\frac{dq}{dt} = k_1(q_e - q_t)
\]

where \(q_e\) and \(q_t\) are the amounts of adsorbate adsorbed at equilibrium and at any time, \(t\) (min), respectively, and \(k_1\) (min\(^{-1}\)) is the adsorption rate constant. Integration of (3) for the boundary conditions \(t=0\) to \(t\) and \(q_t = 0\) to \(q_e\) [10], gives:

\[
\ln(q_e - q_t) = \ln q_e - K_1 t
\]

The following plot of \(\ln(q_e - q_t)\) versus \(t\) will give the slope \(k_1\) and the intercept \(\ln q_e\).

To investigate the mechanism of adsorption kinetics data is tested by using pseudo second order model [8]. Its linear form is expressed as follows:

\[
\frac{t}{q_t} = \frac{1}{k_2 q_{e2}^2} + \frac{1}{q_{e2}} t
\]

The following linear plot of \(t/q_t\) versus \(t\) will give \(1/q_{e2}\) as slope and \(1/K_2 q_{e2}^2\) as the intercept.
B. Adsorption isotherms

Several models have been published in the literature to describe the equilibrium adsorption systems.

The Langmuir and Freundlich equations were used to study the adsorption isotherms of EBT. The linear form of the Langmuir equation [9] is as follows:

\[ \frac{1}{q_e} = \frac{1}{q_0} + \frac{1}{q_0 b} \frac{1}{C_e} \]  

(6)

Where \( q_e \) is the amount of EBT adsorbed at equilibrium, \( C_e \) is the concentration of EBT in solution at equilibrium \( k_f \) and \( 1/n \) are empirical constant which indicate the adsorption capacity and intensity, respectively. Their values were obtained from the intercepts (\( \ln k_f \) and slope \( (1/n) \)) of the following linear plots of \( \ln q_e \) versus \( \ln C_e \). It can be seen that the Langmuir isotherm is a good correlation values, linear plots of the two considered isotherms and the constants are shown in Figures 5 and 6 as well as in Table.3.

The linear form of the Freundlich equation [10] is as follows:

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

(7)

Where \( q_e \) is the amount of EBT adsorbed at equilibrium, \( C_e \) is the concentration of EBT in solution at equilibrium \( k_F \) and \( 1/n \) are empirical constant which indicate the adsorption capacity and intensity, respectively. Their values were obtained from the intercepts (\( \ln k_F \) and slope \( (1/n) \)) of the following linear plots of \( \ln q_e \) versus \( \ln C_e \). It can be seen that the Langmuir isotherm is a good correlation values, linear plots of the two considered isotherms and the constants are shown in Figures 5 and 6 as well as in Table.3.
Table 3. Langmuir and Freundlich parameters

<table>
<thead>
<tr>
<th>Model</th>
<th>$R^2$</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Langmuir</td>
<td>0.93867</td>
<td>$q_0 = 4.83$ (mg$^{-1}$) $b = 0.72$ (l. mg$^{-1}$)</td>
</tr>
<tr>
<td>Freundlich</td>
<td>0.65304</td>
<td>$K_f = 2.55 ((mg/g).l/mg)^{1/n}$, $1/n = 0.65392$</td>
</tr>
</tbody>
</table>

IV. Conclusion

The results did show the retention of the Eriochrom Black T (EBT) dye by the calcinated potatoes peels CPP followed a pseudo second order kinetic model and the Langmuir adsorption model expressed quite well the sorption phenomena.

List of symbols

- $A$: the absorbance
- $b$: Langmuir constant.
- $C$: the concentration of the dye solution at time (t) [mg l$^{-1}$]
- $C_0$: the initial concentration of the dye solution [mg l$^{-1}$]
- $C_e$: the concentration of the dye solution at equilibrium [mg l$^{-1}$]
- $K_1$: the adsorption rate constant for Adsorption kinetics first-order [min$^{-1}$]
- $K_2$: the adsorption rate constant for Adsorption kinetics second-order [g. mg$^{-1}$.min$^{-1}$]
- $K_f$: Constant of Freundlich isotherms [(mg/g). (l/mg)$^{1/n}$]
- $m$: the weight of the adsorbent [g]
- $n$: Second constant of Freundlich isotherms
- $q_e$: the amount of dye adsorbed at equilibrium [mg g$^{-1}$]
- $q$: The adsorption capacity at time (t). [mg g$^{-1}$]
- $q_0$: the maximum adsorption capacity [mg g$^{-1}$]
- $R$: The correlation factor
- $t$: The time of adsorption. [min]
- $V$: the volume of solution [l]

Reference


