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Using natural adsorbent bamboo biochar for rhodamine b removal from aqueous solution

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Abstract: Bamboo biochar was tested for its efficiency in removing Rhodamine B (RB) dye from aqueous solution. The bioadsorption process was measured through equilibrium adsorption isotherms represented by the Langmuir and Freundlich models. Nonlinear regression method was used for the determination of isotherm parameters. An error analysis was undertaken to investigate the effect of applying six error criteria to determine the best-fitting equilibrium model to the experimental data. The equilibrium data for RB adsorption well fited to the Langmuir equation, with maximum monolayer adsorption capacity of 0.638 mg g^{-1}. The present investigations show that bamboo biochar is an alternative adsorbent for RB removal from wastewater.

Introduction

Rhodamine B is widely used as a colorant in textiles and foodstuffs and is one of main organic dyes present in a typical Brazilian agate industry used to give an artificial color pink to the stones. It is important to remove Rhodamine B from effluents because this dye presents carcinogenicity, reproductive and developmental toxicity, neurotoxicity and chronic toxicity (McGregor et al., 1991).

Adsorption is one of the most promising decolorization techniques in dyeing wastewater treatment. The use of waste materials as low-cost adsorbents presents many attractive features, such as, the reduction of costs for waste disposal, therefore contributing to environmental protection (Kyzas et al., 2013). Biochar is a fine-grained and porous substance and exhibits a great potential as an adsorbent because of favorable physical/chemical surface characteristics (Tan at al. 2015). In this study, the objective was to investigate the adsorption behavior of bamboo biochar for the removal of the Rhodamine B from aqueous solution. Langmuir and Freundlich models were used to analyze the adsorption isotherms (Ncibi et al., 2007; Foo, 2010).

Materials and methods

The UV/Visible spectrophotometer (Varian – model Cary 1E) were used. The bamboo biochar was obtained as the residual fraction with small particle size obtained after pyrolysis process. Adsorption experiments were carried out by batch technique. Aliquots of 10 mL of Rhodamine B with initial concentrations 2 - 20 mg L^{-1} were placed in beakers with 0.1 g of bamboo biochar. The suspensions were shaken at 120 rpm for 24 h (25 ± 2 °C). The supernatant was separated by centrifugation for 5 min at 3000 rpm. An aliquot of the supernatant was analyzed using a UV spectrophotometer by measuring absorbance at 554 nm. The amount of the dye uptake and percentage of dye removal by the adsorbent were calculated by applying Eqs. I and II, respectively:

$$q_t = \frac{V(C_o - C_t)}{M} \quad (1)$$

$$R = \frac{100\ (C_o - C_t)}{C_o} \quad (2)$$

Where: qt is the adsorbed amount of adsorbate per gram of adsorbent (mg g-1), Co and Ct is the concentrations of the adsorbate in the initial solution and at any time t, respectively (mg L^{-1}); V the volume of the adsorbate solution added (L) and M the amount of the adsorbent used (g).

The experimental equilibrium data of RB on Bamboo Biochar were compared with the theoretical equilibrium data obtained from the Langmuir and Freundlich isotherm models (Fig. 1). In general, the adsorption isotherm is characterized by isotherm parameters determined by nonlinear regression and the values of error analysis for isotherm models are presented in Table 1 and 2, respectively. The RB removal was between 25-65% in the conditions studied and showed the Langmuir model as the best model that describes the system due the lowest values of each estimate deviation (ARED, SSE, MPSED, HYBRID, SAE and X^2).

Conclusion

In this research, equilibrium biosorption of Rhodamine B dye by Bamboo biochar has been carried out. The related results have been modelled using Freundlich and Langmuir via non-linear regression analysis. The best-fiting model was evaluated using six different error functions. The examination of all these error estimation methods showed that the Langmuir model provides the best fit for the experimental equilibrium data. The Bamboo is available in large quantity in Brazil and can be used as an alternative to existing commercial adsorbents. It can be concluded that Bamboo biochar, is a promising adsorbent for the uptake of RB due to its low cost, easy availability, and high adsorption capacity.

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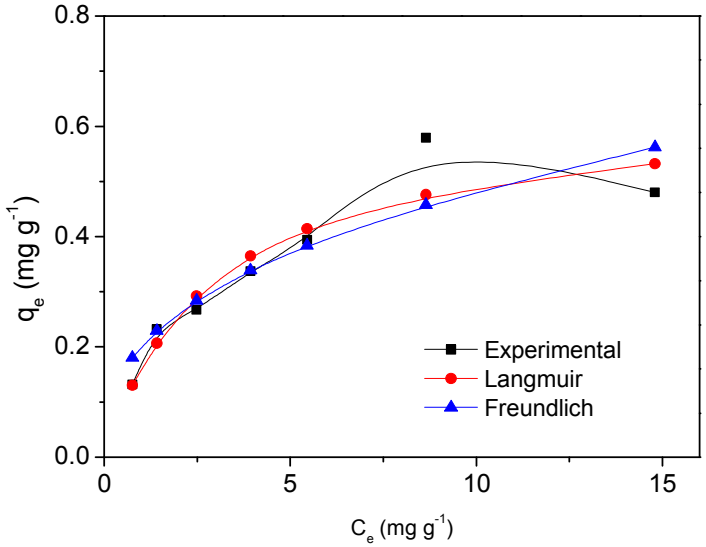

Figure 1: Adsorption isotherm of RB onto Bamboo Biochar (Experimental conditions: adsorbent dose: 0.1 g/10 mL, agitation speed: 120 rpm, contact time: 24 h, temperature: 25 ± 2ºC)

Table 1: The parameters of Langmuir and Freundlich adsorption models for RB onto Bamboo Biochar.

Langmuir	
Q_o (mg g^{-1})	0.638
k_L (L mg^{-1})	0.340
Freundlich	
k_F (mg g^{-1})(Lm g^{-1})$^{1/n}$	0.201
n	2.62

Table 2: Error functions analysis related to the adsorption of RB onto Bamboo Biochar.

	ARED	**SSE**	**MPSED**	**HYBRID**	**SAE**	**X^2**
Langmuir	9.08	0.016	12.1	12.7	0.255	0.036
Freundlich	12.2	0.024	20.7	17.1	0.284	0.058