Colloids and Surfaces A: Physicochem. Eng. Aspects xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Colloids and Surfaces A: Physicochemical and Engineering Aspects

journal homepage: www.elsevier.com/locate/colsurfa

Kinetics and thermodynamics of Rhodamine B adsorption by gelatin/activated carbon composite beads

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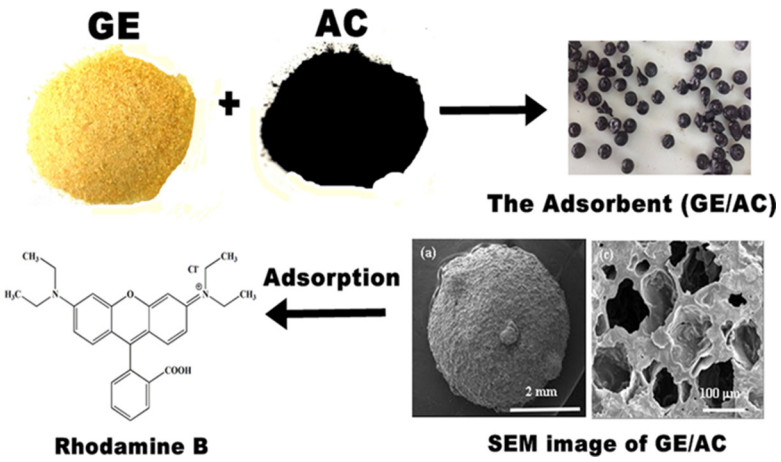
HIGHLIGHTS

- The GE/AC adsorbent beads were prepared by compacting AC and gelatin by facile method.
- The practical potential of GE/AC adsorbent beads can remove Rhodamine B from an aqueous solution.
- The sorption isotherm of Rhodamine B by GE/AC was well fit by the Langmuir model.
- The kinetic of adsorption data of Rhodamine B by GE/AC was best fit with the pseudo-second-order model.
- The equilibrium adsorption at different time by GE/AC indicating an endothermic process.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 3 August 2016
Received in revised form 15 October 2016
Accepted 27 October 2016
Available online xxx

Keywords:
Adsorption isotherm
Rhodamine B
Activated carbon
Gelatin
Kinetics
Thermodynamics

ABSTRACT

The Gelatin/Activated Carbon Composite (GE/AC) adsorbent in bead form was prepared and used to adsorb Rhodamine B from an aqueous solution. Gelatin and activated carbon were combined to an eco-friendly, non-toxic, non-carcinogenic, biocompatible and inexpensive biosorbent. Dependence of sorption performance on key factors, such as contact time, adsorbent dosage, pH, and temperature, were experimentally examined. The effects of initial Rhodamine B concentration were also evaluated, and the response followed Langmuir adsorption isotherm, with the maximum adsorption capacity of 256.41 mg g^{-1} at pH 4 and 30 °C. The results indicate that the GE/AC adsorbent has potential to serve in wastewater treatment applications, especially in batch removal of Rhodamine B from an aqueous solution.

1. Introduction

Various dyes are currently widely used in textiles, leather, papermaking, plastics, food, rubber, and cosmetics industries. They are stable resisting light, heat, and oxidizing agents, and are usually

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http://dx.doi.org/10.1016/j.colsurfa.2016.10.052
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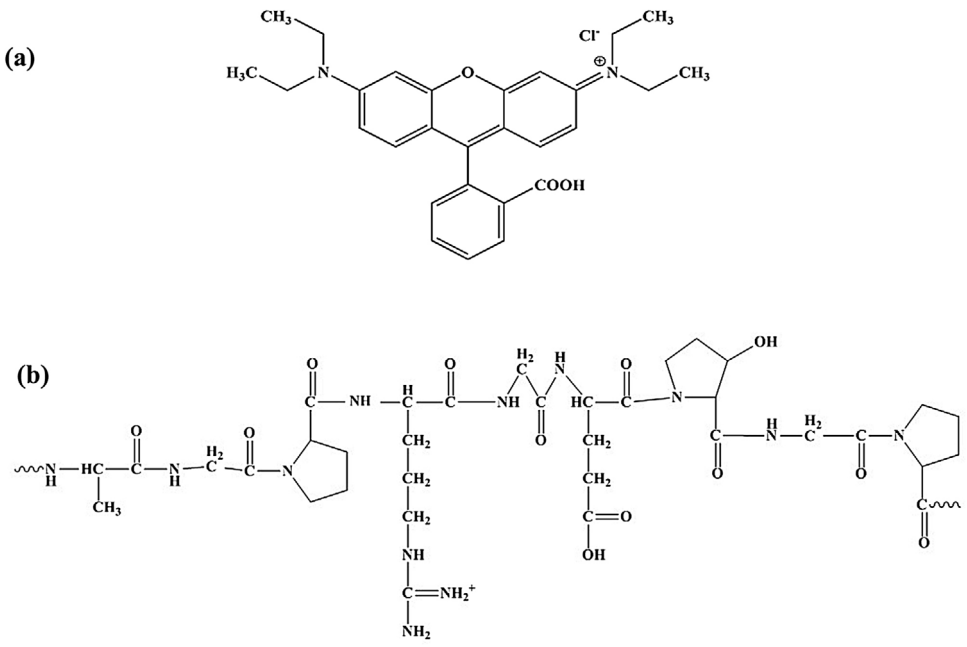

Fig. 1. The chemical structures of Rhodamine B (a), and gelatin (b) [19].

non-biodegradable [1]. Several dyes make their presence strikingly visible by discoloration of water bodies, and more importantly they affect aquatic diversity by blocking sunlight [2]. In addition, discharges of Rhodamine B in natural waters may be harmful to human health. In California, Rhodamine B is suspected to be carcinogenic, so products containing it must present a warning on the label [3]. Practical treatments are necessary to remove this contaminant from wastewater, to avoid emissions. Several such wastewater treatment methods are reported in prior literatures [4–10]. Among the numerous methods, adsorption is the typical mechanism by which toxic organic [11,12] and inorganic pollutants [13], heavy metals [14,15], and dyes [16–18] are removed in these treatments. Activated carbon (AC) powder is the most widely used as adsorbent due to its tremendous surface area available for adsorption. However, AC in powder form is inconvenient in practical use. To overcome this limitations, the effective, eco-friendly and handy granular adsorbent was prepared from biodegradable polymer combined with activated carbon powder. Such adsorbent is expected to be highly effective in terms of adsorption, and simple to use. Gelatin (GE) was chosen because it is a biodegradable polymer, inexpensive, abundant and renewable. A commercial gelatin made from peptone primagen of animal tissue was used, and a basic easy method was selected to make the new adsorbent beads. The chemical structure of GE has amino groups, —NH_2, and carboxylic acid groups, —COOH, as display in Fig. 1(b) [19].

In this work we develop adsorbent beads by compacting AC with gelatin and use these to study adsorption of Rhodamine B dye, which was selected as a representative of the common cationic dyes in effluents from textile and food industries, from wastewater. The structure of Rhodamine B is shown in Fig. 1(a). The aim of this work was to prepare more convenient, effective and low cost adsorbent from gelatin and activated carbon powder. Several studies have reported on kinetics, equilibrium and thermodynamics of adsorption, across various classes of dyes, with activated carbon and other biomaterials as adsorbents. However, to the best of our knowledge, there was a few study of Rhodamine B adsorption by composite beads. Thus, this study explores the development and the practical potential of GE/AC adsorbents to remove Rhodamine B from an aqueous solution. Experimental evaluation and optimization of the key factors affecting performance, namely GE/AC dose, contact time, pH, and temperature, in terms of the adsorption isotherm of Rhodamine B by the GE/AC composite beads, are pursued and discussed in this study.

2. Materials and methods

2.1. Materials and reagents

The adsorbate Rhodamine B, with molecular weight of 479.02 g mol^{-1}, was procured from Fluka, UK. Gelatin powder (GE) and activated carbon (AC) were obtained from Ajax Finechem Pty. Ltd. and Sigma–Aldrich, respectively. Glutaraldehyde, which is a crosslinking reagent, was supplied by Fluka Analytical. NaOH and HCl were purchased from Merck, Germany, for use in adjusting the pH.

2.2. Methods

2.2.1. Preparation of gelatin/activated carbon composite beads (GE/AC)

The GE/AC beads were prepared following the procedure described by Hayeeye et al., 2015 [20]. The AC was sieved to 200–270 mesh size [21] and dried at 110 °C for 24 h before use. A homogeneous solution with GE 30% wt. was prepared by dissolving GE powder of 30 g in distilled water of 70 g. To obtain AC of 10% wt., 10 g of AC was added in to the GE solution of 90 g. The mixture suspension was stirred at room temperature for 30 min, and added dropwise to cold water, causing gelling of the GE. The formed GE/AC beads were filtered and immersed in 1% v/v of glutaraldehyde aqueous solution for overnight, to induce crosslinking in the gel and stabilize it. Finally, the obtained GE/AC beads were dried at 60 °C for 6 h.

2.2.2. Characterization of the GE/AC

Scanning electron microscopy (SEM, Quanta 400) was performed by the Scientific Equipment Center, Prince of Songkla University, to characterize the morphology and the functional groups in GE/AC, respectively.

The adsorbent, GE/AC 10% wt., was characterized in terms of Brunauer-Emmett-Teller (BET) and Barrett-Joyner-Halenda (BJH)

Please cite this article in press as: F. Hayeeye, et al., Kinetics and thermodynamics of Rhodamine B adsorption by gelatin/activated carbon composite beads, Colloids Surf. A: Physicochem. Eng. Aspects (2016), http://dx.doi.org/10.1016/j.colsurfa.2016.10.052