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ORIGINAL ARTICLE

Removal enhancement of basic blue 41 by brick waste from an aqueous solution

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Abstract A modification of brick waste by acid or base solutions was carried out to enhance its physicochemical properties. Treating brick waste with acid did not improve the removal capacity of basic blue 41. However, treating the brick waste with base increased its removal capacity two fold. The adsorption capacity (percentage of removal) decreased from 100% to 10% when the initial concentrations of basic blue and dose of the brick waste increased from 25 to 900 mg/L. The particle size of non treated brick waste affected also the removal capacity; more dye was removed with a smaller particle diameter, at the same initial dye concentrations. The resulting experimental equilibrium data were well-represented by the Langmuir isotherm, and the kinetic data fit a pseudo-second order model well. The maximum removal of basic blue 41 dye was 60–70 mg/g.

1. Introduction

The scarcity of water sources is currently a difficult and ubiquitous problem. Therefore, recycling wastewater is a huge challenge worldwide to safeguard a sustainable future. The textile industry is a potential source of industrial wastewater contaminated with dyes, which can cause serious environmental problems. Because of their chemical structure, the dyes released into water streams might cause ecotoxicity and potentially dangerous bioaccumulation (Moawad et al., 2003; Vadivelan and Vasanth, 2005; Gomez et al., 2007). Various physicochemical methods have been proposed to eliminate the dyes from industrial textile-derived waste waters. Primary clarification methods, including sedimentation and flotation, do not remove colour effectively without simultaneous chemical treatment. Such processes as membrane separation, coagulation and ion exchange are also used to remove colour from dye wastewaters, but the cost of these processes is somewhat prohibitive (Mishra and Tripathy, 1993). The degradation of dyes in wastewater has been also employed, however, these techniques have not been effective due to the nonbiodegradability of most dyes, which are stable to light and oxidation. This has led to study other effective methods, the adsorption technique is proved to be an effective process for the treatment of colourised wastewater (Allen and Koumanova, 2005). This process has an edge over the other methods due to its sludge-free clean operation and complete removal of dyes from diluted solutions, simplicity of design and ease operation (Ozcan et al.,

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2004; Khan et al., 2013; Mittal and Gupta, 2013). Granular activated carbon adsorption is an effective method for removing various organic contaminants and different types of textile dyes, which are classified by their ionic character (Mckay, 1992; Kannan and Meenakshisundaram, 2002). However, the high volume of effluent produced by textile wet processes generates significant expense during the regeneration of the activated carbon (Walker and Weatherley, 1999). Substitutes for activated carbons billed as low-cost alternative adsorbents have been proposed based on their availability as either natural or industrial/agricultural waste or by-products. Several review articles discussing low-cost alternative adsorbents have already been published (Rai et al., 2005; Allen and Koumanova, 2005; Rafatullah et al., 2010).

Natural clays are gaining importance among low-cost adsorbents because their easy and abundant availability and high adsorption capabilities for cations and polar molecules. The presence of net negative charges on clay favours the adsorption of basic dyes (Jiuhui, 2008). There are a large number of clays which are widely used to remove dyes from wastewater, such as kaolinite (Hamdi-Karaoglu et al., 2009), montmorillonite (Almedia et al., 2009), bentonite (Eren and Afsin, 2009), clinoptiolite (Yener et al., 2006), speiolite (Alkan et al., 2004), palygorskite, (Al-Futaisi et al., 2007) and zeolite (Rytwo et al., 2002). Few studies have reported the use of clays calcined at high temperatures as adsorbents for metals or colourant dyes, and the limited examples used calcination temperatures limited to 700 °C (Gil et al., 2013; McKay et al., 1985). Comparison of the contaminant removal abilities of natural and thermally activated smectite clays demonstrates that their activation processes used did not significantly increase their adsorption capacity (Vimonses et al., 2009). The brick building materials were obtained from the calcination of a mixture of clay minerals, sand and other materials at temperatures above 900 °C (Bowler, 1999) any waste generated is reused in the production line of bricks (Demir and Mehmet, 2003), as aggregates in concrete production (Debieb and Kenai, 2008), or in road construction (Guo et al., 2012).

Few studies have reported using brick waste products to remove metals and colourant dyes from polluted solutions (Hamdaoui, 2006; Djeribi and Hamdaoui, 2008; Cheng et al., 2011; El-Shahat and Shehata, 2013). According to our knowledge, the treatment of brick waste by base solution was not performed, while, acidic treatment was proposed by Dehou et al., 2012 to remove metal cations. In this study, we explore the use of a local brick waste as a removal agent for colourant dyes, such as basic blue 41, from artificially polluted water, and we propose its treatment with sulphuric acid or sodium hydroxide solutions at room temperature to modulate its chemical properties, and therefore optimise the removal of basic blue 41. The brick waste and its acid- or base-treated counterparts were characterised before being used in the removal process. Batch experiments were conducted to study the effects of the initial concentration, dose volume, particle size of the crushed brick waste, contact time and pH on the dye elimination. Kinetic studies indicated that more than 95% of the dye was removed in 2 h. Brick waste has a removal capacity of 50 mg g^{-1}, which can be achieved at a low adsorbent dose and volume, and exceeded this value for the base treated brick waste.

2. Experimental

2.1. Materials

The brick waste (WB) was obtained from Al-Maimani Red Bricks, which is a local brick manufacturer in Al-Madinah Al-Munawwarah, Saudi Arabia. The samples were crushed using a hammer and ground with a householder grinder before being screened with mechanical sieves to obtain six different particle sizes: 2 ± 1 mm, 1 ± 0.5 mm, 0.5 ± 0.225 mm, 0.225 ± 0.125 mm, 0.125 ± 0.062 mm, and 0.065 ± 0.0044 mm. The above fractions were used without any further treatment. The chemical treatment and the study of the different material parameters on the removal of BB-41 were performed using WB 0.225 ± 0.125 mm in diameter, unless otherwise noted.

In some cases, brick waste with $0.220 \text{ mm} \pm 0.125$ mm particles was treated with an inorganic acid ((H_2SO_4) or alkali (NaOH) solution. The modification was performed as follows: five grams of brick waste were mixed with 50 mL of sulphuric acid (at different concentrations 2 M, 4 M and 6 M) or 50 mL of NaOH (4 M) solution at room temperature overnight. The choice of the NaOH solution of 4 M was based on our preliminary adsorption experiments. The solid was collected by filtration, washed with distilled water several times, and dried at room temperature. The samples were designated as follows: A2-BW, A4-WB and A6-WB correspond to WB treated with 2M, 4M, and 6M acid solutions, respectively. B4-WB corresponds to WB treated with a 4M basic solution.

2.2. Batch mode adsorption studies

Basic blue 41 (BB-41) of analytical grade was purchased from Sigma–Aldrich, and used without further purification. It has the molecular formula C20H26N4O6S2 (mol. weight. 482.57 g/mol) with a colour index Number 11105. The structure of the basic blue 41 is shown in Fig. 1.

Batch mode adsorption studies with basic blue (BB-41) were carried out to investigate the effect of different parameters, such as the initial BB-41 concentration, sorbent dose, the volume of added BB-41 and the pH of the solution before adsorption. Known amounts of sorbent (0.1 g) were placed in 12 mL centrifuge glass tubes containing 10 mL of BB-41 solution. The tubes were shaken at 120 rpm at 30 °C for 18 h to reach equilibrium before being centrifuged for 10 min at 5000 rpm. The collected solution was diluted before analysis. The adsorption behaviour of the samples was studied by evaluating the percentage removal efficiency and the amount of adsorbed BB-41.

2.3. Characterisation

Mineralogical analysis of the brick waste was carried out using powder X-ray diffraction (PXRD) with advance 8 (Ni-filtered

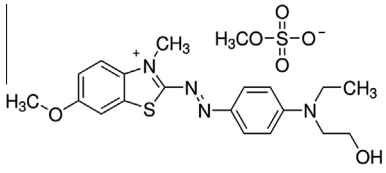

Figure 1 Structure of the dye basic blue 41.