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Highly efficient removal of basic blue 41 with nanoporous silica

Mansoureh Zarezadeh-Mehrizi *, Alireza Badiei *

School of Chemistry, College of Science, University of Tehran, Tehran, Iran

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ABSTRACT

The adsorption characteristics of basic blue 41 from aqueous solution were investigated using nanoporous silica (NPS). NPS with an average pore diameter of 2.4 nm and a surface area of 1030 m^2/g was synthesized by using nonyl phenol ethoxylated decylether (NP-10) as structure directing agent (SDA) and ethyl silicate 40% (ETS-40) under acidic condition. This adsorbent was analyzed by means of small-angle X-ray scattering, scanning electron microscopy, N_2 adsorption–desorption isotherm and Fourier transforms infrared spectroscopy. The kinetic data reveals that the adsorption process follows the linear form of the pseudo-second-order model. The adsorption isotherm was fitted well to the Langmuir data. The monolayer adsorption capacity of adsorbent was found to be 345 mg/g.

1. Introduction

Synthetic dyes are widely used in different industries such as textile, leather, cosmetics, plastics, and food, annually [1]. Colored effluents of these industries not only have a negative effect on the aquatic system because of the blocking sunlight for photosynthesis process but also can be identified as the toxic and carcinogenic materials [2]. Azo dyes are the most common group of dyes used in textile industries because of their low cost, stability and variety of colors [3]. They are biologically non-degradable because of their aromatic structure, thereby, removal of these dyes are very important in

* Corresponding author. Tel.: +982161112614; fax: +982166495291.
E-mail addresses: mansourezare@gmail.com (M. Zarezadeh-Mehrizi), abadiei@khayam.ut.ac.ir (A. Badiei).

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view point of the ecosystem and restriction on the water availability. There are various methods to remove dyes such as coagulation/flocculation, biological treatment, chemical oxidation, photocatalysis, membrane filtration, liquid–liquid extraction and adsorption [4–13]. Among these methods, adsorption has a good reliability for the industries due to easy operation, cost-effectiveness, high efficiency and water reuse. Different kinds of adsorbent are used for the removal of synthetic dyes such as activated carbons, zeolite, fly ash, graphene oxide and nanooporous silica [14–20]. Nanoporous silicas have attracted increasing attention because of high surface area and pore volume, adjustable pore diameter, their simple synthesis, high thermal and hydrothermal stability. Among different kinds of nanoporous silica, the family of MSU-X has a wormhole-like pore structure which facilitates the diffusion of reacting species to the reactive site. Despite this characteristic of MSU-X, there are a few studies that MSU-X materials are used as the adsorbent. Nanoporous silica and functionalized nanoporous silica have been used for dyes removal [9,21–23]. Research on the dye adsorption is limited to a few kinds of dyes such as methylene blue, phenosafranine and night blue [9,14,15,18,19,24–30] but there are a few reports about the adsorption of basic blue 41 [31–33].

In this study, NPS was prepared using NP-10 as a SDA and ETS-40 as a silica source in acidic media. The surfactants were removed from the framework by ethanol extraction and followed heating at 350 °C. The synthesized NPS used for the adsorption of basic blue 41, water-soluble cationic dye, as it is widely used in the textile industry. The adsorption behavior was evaluated by kinetic and isotherm studies.

2. Experimental

2.1. Materials

The chemicals used for the synthesis: ethyl silicate solution (ETS-40, Wacker, SiO_2 40%), nitric acid (Merck, 65%), nonyl phenol ethoxylated decylether (Hulls, NP-10, Mw=660 g/mol), basic blue 41 (Ciba, M_w=452.58 g/mol, hereafter designated as BB 41), Ethanol and dionized water. Fig. 1 shows the chemical structure of BB 41.

2.2. Synthesis of nanoporous silica (NPS)

NPS was prepared as reported previously, using NP-10 as a SDA and ETS-40 as a silica source under acidic conditions [34]. Briefly, surfactant was dissolved in an acidic solution under stirring at 30 °C. Then, 196 g of ETS-40 was added to this solution and it was kept at 80 °C under stirring at 400 rpm during 5 h. the final composition is 1 SiO_2, 0.06 NP-10, 3.9 HNO_3 and 110 H_2O. The solid product was filtered, washed with deionized water and dried. Finally, the white solid was recovered after ethanol extraction with a Soxhlet apparatus and a further heating at 350 °C in air.

2.3. Batch adsorption experiment

Dye adsorption experiments onto NPS were performed by mixing 20 ml of BB 41 solution of desired initial concentration with 0.01 g of NPS at 30 °C. The pH of the solution was adjusted to 7 using dilute NaOH solution. Isotherm experiments were carried out at initial dye concentration from 48 to 360 mg/L. BB 41 adsorption kinetics over NPS were evaluated at different concentrations (20–60 mg/L) at predetermined time intervals between 5 and 180 min. The solid and liquid phases were separated

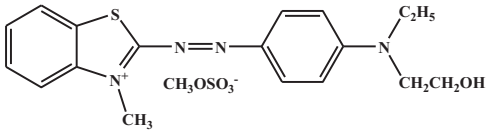

Fig. 1. Chemical structure of BB 41.