Iranian Polymer Journal (2018) 27:527–535
https://doi.org/10.1007/s13726-018-0630-9

ORIGINAL RESEARCH

A biopolymer-based composite hydrogel for rhodamine 6G dye removal: its synthesis, adsorption isotherms and kinetics

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Received: 20 October 2017 / Accepted: 28 April 2018 / Published online: 8 June 2018
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Abstract

The present study reports the preparation and application of a novel biopolymer-based composite hydrogel (BCH) for removal of synthetic dye rhodamine 6G (Rh6G). BCH was prepared from biopolymer chitosan and acrylic acid monomer, in the presence of initiator ($K_2S_2O_8$) and cross-linker thiourea using microwave irradiation. Synthesized chitosan-based composite hydrogel was characterized by using analytical techniques including Fourier transform infrared spectroscopy (FTIR), thermogravimetric analysis (TGA), derivative thermogravimetric analysis (DTA) and differential thermal analysis (DTG). The stability of the adsorbent was demonstrated from its water uptake capacity. The dynamics of water sorption study showed the Fickian behavior. The investigations were continued to assess the adsorption potential of BCH for removal of Rh6G from aqueous solution. The effect of process parameters affecting the adsorption of rhodamine 6G (Rh6G), such as adsorbent dose, initial concentration of pollutant, contact time and pH of the solution was evaluated. Removal efficiency of chitosan-based composite hydrogel (BCH) was found to be 87.31% at pH 7 for BCH dose of 1 g/L after 8 h. The obtained data were fitted to adsorption isotherms and kinetics models. The adsorption equilibrium isotherm and kinetics studies indicated that the pseudo-second-order model and the Freundlich model well described the adsorption equilibrium of Rh6G on BCH.

Keywords Chitosan · Adsorption · Rhodamine 6G dye · Microwave radiation · Adsorption isotherms and kinetics

Introduction

The effluent from textile and dyeing industry is toxic and hazardous for the environment, as the by-products of synthetic dyes formed due to the chemical reactions often remain present in wastewater. Different pollutant removal techniques, such as biological treatment, chemical coagulation, membrane separation, oxidation, sorption and many other processes have been used to treat wastewaters [1–3]. However, adsorption is one of the efficient and economic processes for the removal of dyes from industrial wastewater streams [4]. A large number of non-conventional adsorbents have been examined for their ability to remove pollutants from wastewater, but the use of adsorbents containing natural polymers, such as chitin and chitosan and their derivatives has received greater attention in the recent past [5, 6].

Chitosan, a linear hetero-polymer, is obtained by partial alkaline deacetylation of chitin. It is a second most abundant biomaterial, found in the exoskeleton of crabs and others such as arthropod prawns, lobsters and shrimps [7]. Chitosan exhibits hydrophilicity, biodegradability, and antibacterial activity and finds application in treatment of pharmaceutical and biomedical wastewater treatment [8]. The literature suggests the potential of chitosan [9–11] and its derivatives as adsorbents for removal of various classes of pollutants [12, 13]. However, its low porosity, weak mechanical strength, less stability and crumbling tendency impair its application as a potential material for wastewater treatment [14]. The research studies undertaken for modification of chitosan to improve its solubility characteristics and adsorption properties include chemical functionalization, grafting and polymerization with other monomers or polymers and preparation of composites [15, 16].

The cross-linking of chitosan in the presence of other polymers to develop a potential interpenetrating network

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