Journal of Environmental Chemical Engineering 5 (2017) 319–327

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

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

Exploring the adsorption behavior of cationic and anionic dyes on industrial waste shells of egg

M.A. Abdel-Khalek, M.K. Abdel Rahman, A.A. Francis*

Central Metallurgical Research and Development Institute—CMRDI, Cairo, Egypt

ARTICLE INFO

Article history:
Received 25 August 2016
Received in revised form 27 November 2016
Accepted 29 November 2016
Available online 30 November 2016

Keywords:
Industrial waste shells of egg
Adsorption kinetics
Equilibrium isotherms
Thermodynamics
SEM

ABSTRACT

The objective of this work is to investigate the feasibility of using the whole eggshell matrix (eggshell + membrane) as a potential and low-cost bio-sorbent for color removal from dyes. The two tested dyes (Methylene blue, MB & Congo red, CR) revealed different adsorption behaviors reflecting the complex nature of the interaction between the adsorbent surface and these molecules. The functional groups and surface morphologies of untreated eggshell powder and adsorbed Eggshell were analyzed by Fourier transform infrared spectroscopy (FTIR) and field emission scanning electron microscopy (FESEM). The electrical double layer mechanism explained the adsorption behavior of MB cations onto the eggshell surface, whilst that of the CR anions favored the electrostatic attraction on the positively charged surface of eggshell at lower pH. The adsorption of dyes on the surface of eggshell follows a second order kinetics, while the adsorption isotherm obeys the Freundlich model and exhibits multilayer adsorption. The maximum adsorption capacity was estimated to be 94.9 mg/g and 49.5 mg/g for MB and CR respectively for a concentration of 1000 mg/l at room temperature. The heterogeneity of the eggshell surface may cause rearrangement of dye molecules once they are primarily adsorbed. The free energy of adsorption showed an increase with temperature, indicating the occurrence of physical adsorption. The present results indicate the suitability of bio-composite eggshell wastes to be used as adsorbent for the removal of dyes.

1. Introduction

From the environmental point of view, adsorption process has been considered to be an effective method to treat effluents and for the removal of different color from aqueous solutions [1]. Since the last two decades, significant number of works has been reported on the use of activated carbon as one of the most popular adsorbent for treating effluents and dye-containing waste solutions [2,3]. However, its cost of disposal [4] has diverted the attention to the use of cheap or natural adsorbents such as shale oil ash [5], chitosan [6], sunflower stalk [7], natural clay [8,9,3], orange peel and soy meal hull [10,11].

In the present work, we are exploring the adsorption potential of bio-composite eggshell as a common household byproduct toward the basic and acid dyes (methylene blue and congo red). There have been a number of interesting studies that revealed the adsorption capabilities of industrial waste shells of egg [12–17]. These investigations have been focused on the feasibility of using eggshells (ES) as a low cost bio-sorbent for the removal of dyestuffs from aqueous solution such as reactive red 123 [12], methylene blue [13], Malachite Green [14], Direct Red 28 [15], Reactive Yellow 205 [16], Direct Red 80 and Acid Blue 25 [17].

Liao et al. [18] and De Paula et al. [19] have mentioned that derivatives from industrial waste shells of egg could be used to remove toxic metals (e.g. lead, cadmium and copper) from aqueous solution. Eggshell wastes had also been exploited as an alternative to calcium carbonate for the immobilization of heavy metals in soils [20]. Avrami et al. [21] evaluated the adsorption effectiveness of both Acid Red and Acid Blue onto the Egg shell membrane with respect to initial dye concentrations, pH, contact time, particle sizes and bio-sorbent doses at room temperature. These results may then be used in conjunction with the work of Otun et al. [22] and Ahmad et al. [23] on the use of eggshell wastes for the removal of heavy metals e.g. Cd (II), Cu (II), Cr (III), Fe (III), Ni (II) and Pb (II) from aqueous solutions.

A detailed investigation on the adsorption behavior, kinetics and equilibrium for the effective removal of color from basic and acid dyes using the industrial waste shells of egg has been discussed. The effects of dye concentrations, pH, and contact time on the adsorption of both dyes onto the whole eggshell matrix

* Corresponding author.
E-mail address: adel_francis@hotmail.com (A.A. Francis).

http://dx.doi.org/10.1016/j.jece.2016.11.043
2213-3437/

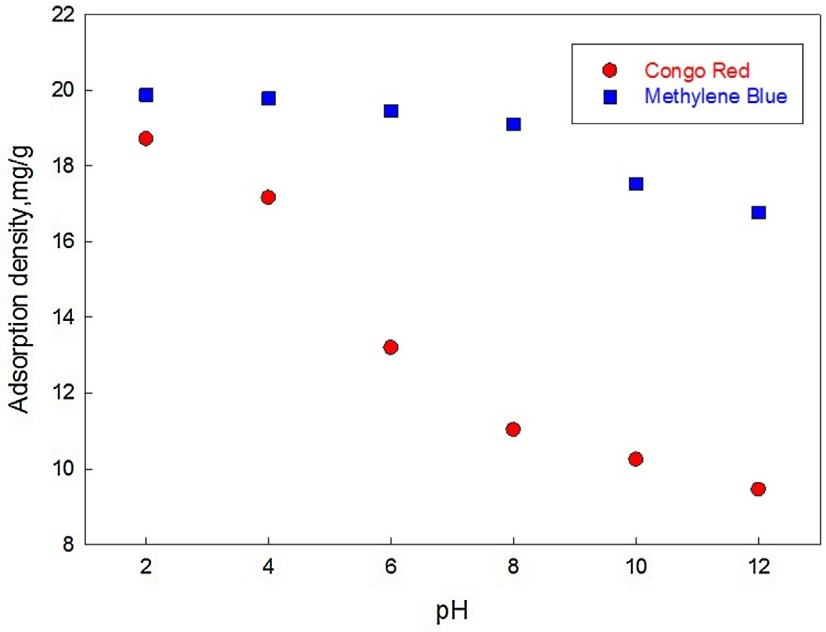

Fig. 1. Variation of the adsorbed amount MB and CR on eggshells with pH.

(eggshell + membrane) were analyzed by Langmuir and Freundlich adsorption isotherms. Based on isotherms adsorption data, thermodynamics parameters such as free energy, enthalpy, and entropy of adsorption were also evaluated. The present work continues on the general theme of exploring the environmental, social, technological and economic advantages of this waste material not only for the removal of dye pollution or metal-contaminated wastewater, but also for the implementation of cleaner production processes and converting waste into industrially viable resources [24]. It should be noted that the antibacterial activities of ESM against various types of bacteria, including Escherichia coli, and the ability of eggshell membrane (ESM) proteins to interact and disrupt the membrane integrity of bacteria were demonstrated by Poland et al. and Mine et al. respectively [25,26]. The use of the whole eggshell matrix (ESM &ES) is a major advantage in terms of cost, energy and process requirement. While no process is perfect, reducing the need for calcination and washing of eggshells or even separation of ESM from ES prior to processing has a major impact on cost-benefits and efficiency of adsorption process. Consequently, this work has a particular focus

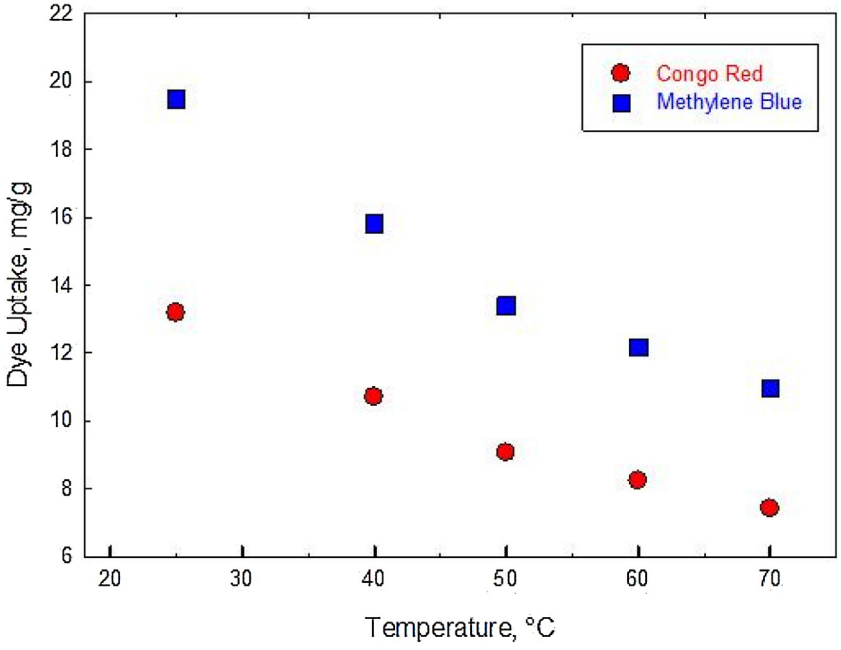

Fig. 2. Effect of temperature on the amount of adsorbed MB and CR on eggshells.