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Biosorption of dye from textile wastewater effluent onto alkali treated dried sunflower seed hull and design of a batch adsorber

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ABSTRACT

Alkali treated dried sunflower seed hull (DSSH) was used as adsorbent for the decolorization of wastewater effluent from the textile industry. Batch adsorption studies were performed as a function of contact time, initial solution pH, initial dye concentration, adsorbent dosage and temperature. Kinetic analysis revealed that adsorption experimental data was best fitted by pseudo-second order model at all textile dye concentrations tested. Based on the pseudo-second order rate constants obtained using Arrhenius and Eyring equations, the activation parameters for the formation of activated complex between Textile dye molecules and dried sunflower seed hull were determined: namely the activation energy (8.79 kJ/mol), the change of entropy (−39.57 kJ/mol/K), enthalpy (8.79 kJ/mol), and Gibbs free energy (range 6.27–8.11 kJ/mol). The equilibrium adsorption data was found to follow the Langmuir isotherm model and maximum monolayer capacity was found to be 169.5 mg/g at 25 °C. The Langmuir isotherm model was applied to the design of a single-stage adsorber. From the thermodynamics analysis the magnitude of enthalpy change (ΔH) was found to be 8.79 kJ/mol; indicating that physical forces were involved in biosorption of dye onto DSSH.

1. Introduction

Dyes are color organic compounds released in effluent water of industries such as textiles, leather, paper, printing, and cosmetics. The textile sector alone consumes about 60% of total dyes produced to paint various fabrics, but 10–15% of dyes used for this purpose comes out through the effluents [1]. Discharging dyes into the hydrosphere have long term adverse effects on the environment as dyes give water undesirable color, reduce sunlight penetration and are objectionable for drinking and other uses [2,3]. Dyes are visible to human eye and therefore, a highly objectionable type of pollutant on esthetic grounds. They also interfere with the transmission of light and upset the biological metabolism processes which cause the destruction of aquatic communities present in ecosystem [4]. The textile-dying industry consumes large quantities of water and produces large volumes of wastewater from different steps in the dyeing and finishing processes. Wastewater from printing and dyeing units is often rich in color. The presence of even very low concentrations of dyes in the effluent is highly visible and undesirable. The effluent also contains residues of reactive dyes and harmful chemicals. Therefore, such wastewater needs to be properly treated before its release into the environment [5]. Various treatments have been applied for the removal of synthetic dyes from wastewaters such as coagulation, flocculation, ion exchange, membrane filtration, photo-catalysis and photo-oxidation but major drawbacks of these technologies are long operation time, high sludge production, high cost, and eco-unfriendliness. Adsorption is emerging as a growing alternative technique for the decolorization of dye containing effluents. The major advantage of adsorption is use of low cost material especially agricultural based biomass. Various biomass have been studied as potential biosorbents such as saw dust cactus fruit peel [3], chitosan [4], saw dust [6], leaves of *Posidonia oceanica* [7], oil palm empty fruit bunch fibers [8], sugar beet pulp [9], modified walnut shell [10],*Pyracantha coccinea* berries [11], rice 47 husk ash [12,13], eggshell [14], mango seed kernel powder [15] and jackfruit leaf powder [16].

The objective of this work was to investigate the potential of dried sunflower seed hull (DSSH), an agricultural waste, as an adsorbent in the removal of synthetic reactive and direct dyes, from aqueous waste effluent from the textile industry. To the best of our knowledge, DSSH has not been used yet for textile dye removal from aqueous solutions. The effects of some operating variables such as pH, adsorbent weight and initial dye concentration on the kinetics of the adsorption textile dye (TD) are also

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considered. The design of a single-batch adsorber is also studied in this work in order to consider the industrial (large scale) applicability of the biosorbents in the removal of TD from wastewater.

2. Material and methods

2.1. Preparation of alkali dried sunflower seed hull

A 120 g packet of Sunflower seeds purchased from a local grocery was dehulled and the hull was milled in a coffee grinder for about 10 min. The milled hull was then sieved through the ASTM sieve size #60 (250 μm aperture). Twenty grams of milled sunflowers seed hulls (SSH) was then soaked in 100 mL of (0.05 M) NaOH solution and left overnight. The alkali treated SSH material was washed several times with distilled water until the pH of the supernatant was around 6.5. The wet SSH was dried overnight at 70 °C in a forced air drying oven to constant weight. The dried sunflower seed hull (DSSH) was stored in a zip-lock bag and used in the adsorption characteristics studies.

2.2. Preparation of textile dye solution from wastewater and analytical Methods

Textile wastewater effluent was a gift from Cotton Incorporated Cary, NC. The sample was taken from the neutralization tank and it contains chemicals related to the bleaching and synthetic reactive and direct dyes used in dyeing of cotton fabric. The total solids content of the concentrated textile effluent wastewater was determined by drying 50 mL of dye solution in triplicates at 103 °C for 3 h. It was found to be 73.3 g/L. The maximum absorbance wavelength, for a 1:10 dilution dye solution, was determined using Gensys 5 UV–vis spectrophotometer. Two maximum absorbance were observed at 620 and 644 nm. The absorbance at 620 nm was higher and was therefore used throughout the study to minimize interference effect. Using this wavelength the calibration plot of absorbance versus concentration was determined. The calibration plot was linear up to TD concentration of 7330 mg/L. Various dilutions of the concentrated TD solution were used in the batch experiments.

2.3. Batch biosorption studies

Batch biosorption experiments were performed in 50 ml plastic tubes by adding 400 mg of DSSH to 20 mL of diluted textile dye (TD) solution of different initial concentrations ranging from (1470–7330 mg/L) and the mixture was stirred using vortex mixing. Aliquots of 1 mL were withdrawn at preset time intervals and the absorbance of the solution was measured using a GENESYS 5 Scanning Spectrophotometer (Thermo Scientific, Madison, WI, USA). The concentration of the textile dye in the supernatant was determined from the calibration plot of absorbance at 620 nm versus concentration. All experiments were conducted at 25 °C while temperature studies were conducted at 19, 30, 35, 40, 45, 50 and 60 °C. Kinetic studies were performed at different concentrations (1170, 2430, 5860, 7330, 11,330, 14,660 mg/L) with 400 mg of the DSSH.

The amount of TD biosorbed per gram of DSSH was calculated using the following equation:

$$q_t = \frac{(C_0 - C_t)V}{M} \quad (1)$$

where q_t is the biosorption of TD per gram of DSSH (g/g); C_o is the initial concentration of TD (g/L) C_t is the TD concentration at time t

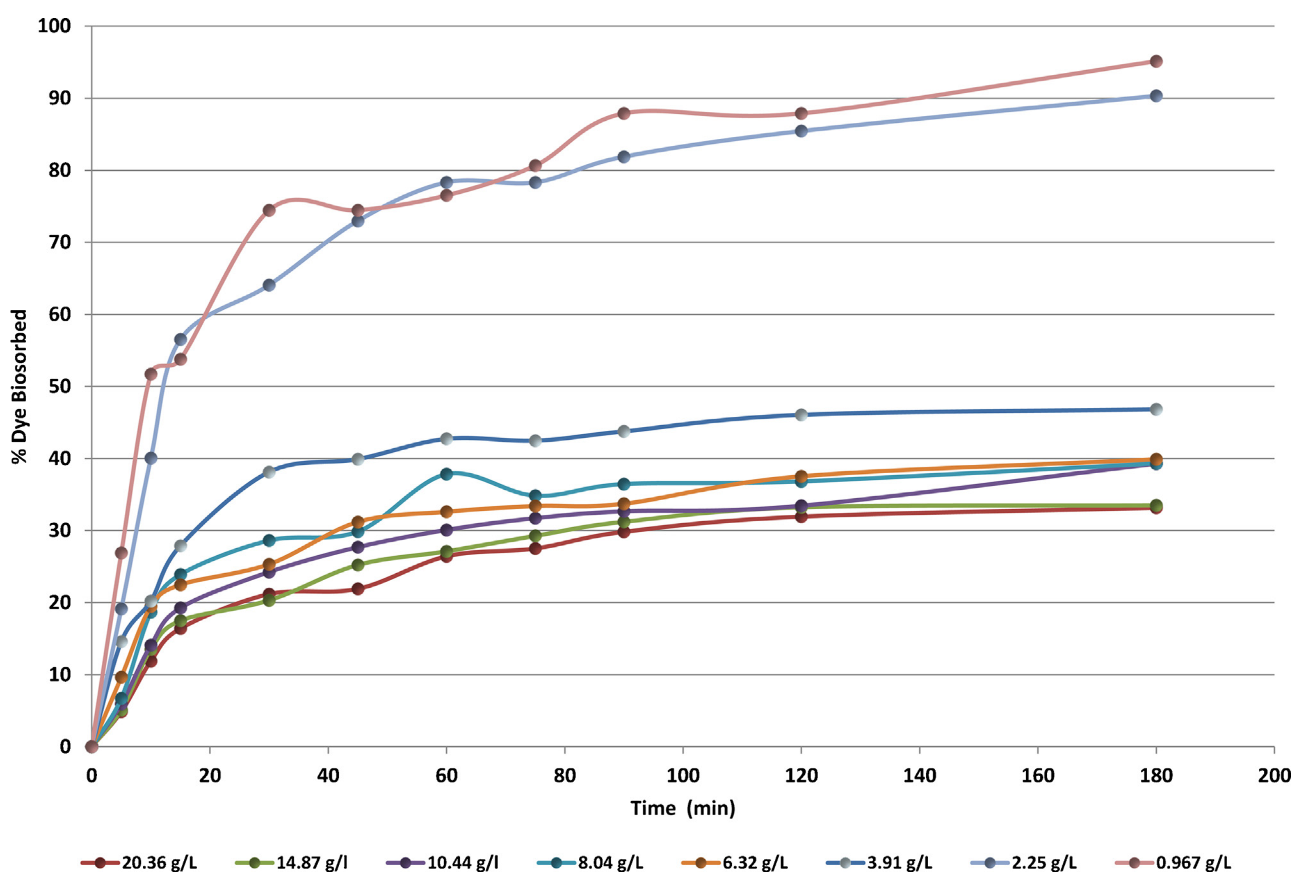

Fig. 1. Effect of contact time on the adsorption of TD on DSSH at 25 °C.