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Isotherm and kinetic studies of Burazol Blue ED dye biosorption by dried anaerobic sludge

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ABSTRACT

Biosorption potential of dried anaerobic sludge (DAS) for Burazol Blue ED (BB) was studied with respect to pH, equilibrium time, initial dye concentrations and temperature to determine equilibrium and kinetic models. The most suitable pH, equilibrium time and initial dye concentration were determined as 0.5 ± 0.03, 75 min and 150 mg/L, respectively, at a biomass dosage of 0.4 g/L and $25\,^{\circ}C \pm 1.0$. The equilibrium data was best described by the Langmuir isotherm model. Maximum uptake capacity (q_m) of DAS for the dyestuff (BB) were 118.3, 125.8 and 127.5 mg/g biomass at temperatures of 25, 40 and 50 °C, respectively, indicating that the biosorption process is spontaneous and favored at higher temperatures. The overall biosorption process was best described by pseudo-second-order kinetic model. Gibbs free energy changes were calculated as −356.8, −519.7 and −520.6 J/mol at 25, 40 and 50 °C, respectively.

1. Introduction

Dye molecules have synthetic origin and their structures differ in terms of chemical composition, molecular weight and toxicity. They can be classified as anionic (acid, direct and reactive dyes), cationic (basic dyes) and nonionic (disperse dyes) dyes according to their dissociation in an aqueous solution [1]. They are consumed in a great number of industries such as textile, pesticide, paint, solvent, pharmaceutics, paper and pulp as well as petroleum. Effluents of these industries contain undesired quantities of chemicals and cause a big concern from environmental point of view. Such effluents need to be treated properly before they are released to the receiving waters [2,3].

Conventional dye treatment technologies are based on physicochemical principles and their applications are limited due to various reasons such as high cost and low efficiency. For example, the large-scale applications of activated carbon cited as one of the best available control technologies by the US Environmental Protection Agency are hampered by high operating costs, relatively high price and problems with regeneration [3]. In recent years, many non-conventional low-cost adsorbents of natural material (wood, coconut shell, lignite, coal) [3], biosorbents (bacteria, fungi and algae) [4,5] and waste materials (seeds of *Capsicum annuum*, cotton waste, palm fruit bunch and aquatic plants) from industry and agriculture were proposed [6–8]. They are cheap to produce and carry wide range of binding sites for dyes molecules. This technology, using above biological biomass as adsorbing materials, is named as biosorption. It is based on the property of microbial biomass to sequester toxic molecules such as dyes through interactions between toxic molecules and the functional groups present on the cell wall surface of the biological cells. They are mainly composed of polysaccharides, proteins and lipids [9].

For this reason, it would be interesting to investigate whether dried anaerobic sludge (DAS) constitutes an ideal material to be used as a biosorbent for the removal of Burazol Blue ED (BB) dye or not. The anaerobic sludge is a well known biomass mainly consisting of both bacteria and protozoa, which means that there could be ample amount of binding sites for the dye molecules. It is also cheap, readily available in large quantities and has been previously used to remove some hazardous materials such as Methylene Blue [10], Rhodamine B [11], mono chlorinated phenols [12] and Reactive Black 5 [13].

BB is an anionic dye which is one of the commonly used dyes in textile industry of Turkey. Its removal from contaminated water causes a big concern from environmental point of view. To the

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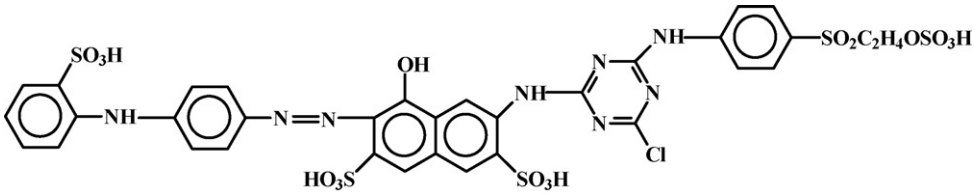

Fig. 1. The chemical structure of Burazol Blue ED dye.

best of our knowledge, BB dye biosorption by DAS is not reported. Therefore, the present work investigates the biosorption potential of DAS for the removal of BB dye from aqueous solutions in a batch study with variation in the parameters of initial pH, contact time and initial dye concentrations. The equilibrium binding has been described in terms of Langmuir and Freundlich isotherms. Kinetic data were evaluated according to the pseudo-first order, pseudo-second-order kinetics and intraparticle diffusion model from which the rate constants of biosorption and equilibrium capacity were determined. The Gibbs free energy values were also calculated at all studied temperatures.

2. Materials and methods

2.1. Preparation of anaerobic sludge

A mixed anaerobic sludge (whose suspended solids were 60 g/L and volatile suspended solids 38 g/L) was obtained from the anaerobic digesters of Ankara Municipal Wastewater Treatment Plant, Turkey. It is a complex consortium microorganisms mainly containing archaebacteria (methanogens). The biomass was washed thorougly with distilled water twice, followed by spreading on Petri dishes and dried in an oven at 60 °C overnight. It was then powdered using a mortar and pestle and sieved to select particles of approximately 150 μm for use as a biosorbent.

2.2. Preparation of dye solution

Burazol Blue ED (BB) dye ($C_{38}H_{41}N_8O_{16}S_5Cl$: 1061.54 g/mol) (Fig. 1) was obtained from BURBOYA textile company in Bursa, Turkey and used without further purification. As shown in Fig. 1, BB dye has five sulfonate groups, which have negative charges in aqueous solutions. The tests solutions containing BB dye were prepared by diluting 1.0 g/L of stock solution which was prepared by dissolving an accurate quantity of dye in distilled water.

2.3. Experimental procedure

Laboratory biosorption experiments were optimized at the desired pH value, contact time and different initial BB dye concentrations. The batch experiments were carried out in a stoppered conical flask (250 mL) at an agitation speed of 200 rpm on a magnetic stirrer. Throughout the study, the pH was varied from 0.5 to 6.0, the contact time from 10 to 90 and the BB dye concentration from 25 to 300 mg/L at constant biomass feed of 0.4 g/L. The experiments were repeated at 25, 40 and 50 °C. When the sorption procedure was completed, the solutions were centrifuged at 4500 rpm for 10 min and the supernatants were then analyzed for residual BB dye concentrations using a spectrophotometer, (UV–vis, Cecil 4002) at λ_{max} 594 nm. The solutions involved were diluted to known concentrations, to give absorbancies in the range of 0.1–1.0, before making the measurements.

The biosorption capacity was determined by using the following equation taking into account the concentration difference of the solution at the beginning and at equilibrium:

$$q_e = \frac{(C_i - C_e)V}{m} \quad (1)$$

where C_i and C_e are the initial and the equilibrium dye concentrations (mg/L), V is the volume of solution (L) and m is the amount of biomass used (g).

The negative controls (with no biomass) were prepared and run simultaneously. Experimental data were the mean values from two independent experiments.

3. Results and discussion

3.1. Effect of pH

The pH is an important parameter for biosorption studies and affects not only the biosorption capacity, but also the color and solubility of dye solutions. The maximum biosorption capacities of DAS were plotted against the equilibrium pH using 50 mL of 150 mg/L initial dye solution and 0.02 g biomass dose at 25 °C for a prefixed time period (60 min) in Fig. 2. As shown in this figure, the equilibrium uptake capacity of the biomass decreased from 105.8 to 71.6 mg/g biomass when the solution pH was changed from 0.5 to 1.5. This trend was followed by a sharp decrease up to pH 2.0, which caused the equilibrium uptake capacity to drop from 71.6 mg/g biomass to 3.0 mg/g biomass. The biosorption capacity further decreased to the lowest level of 1.0 mg/g biomass at pH 5. From this study, the optimum pH was determined as 0.5 at which the maximum biosorption capacity of DAS for BB dyes was determined as 105.8 mg/g biomass at 25 °C. This effect was largely related to the anionic characters of BB dye. Weak base groups on the biomass surface were protonated and acquired a net positive charge with diminishing solution pH. This caused a significantly high electrostatic attraction between the surface of DAS and BB dye and as a result, a high biosorption capacity [14].

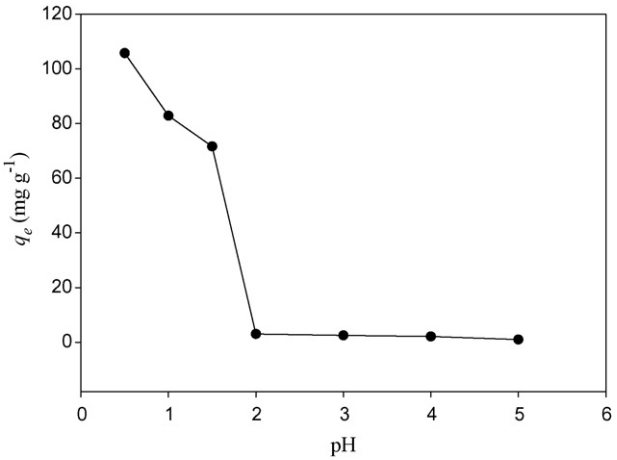

Fig. 2. Effect of pH for the biosorption of BB dye onto DAS at 25 °C (dye concentration: 50 mL of 150 g/L; biosorbent dose: 0.4 g/L; contact time: 60 min).