507h An Investigation of the Adsorption Properties of Saudi Bentonite Clay for Dyes in Wastewater

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ABSTRACT

A Saudi bentonite natural clay was investigated as an adsorbent for the Basic Blue 3 dye from wastewater. A batch adsorber was used to determine the external mass transfer coefficient, the pore diffusivity and the equilibrium isotherms, and a fixed bed adsorber was used to determine experimental breakthrough curves for the dye. The adsorbent used in the experiments was Saudi bentonite clay obtained from Khulays Mine in Saudi Arabia. The specific pore volume, solid particle density and porosity values are equal to 0.0778 cm3/g, 2.6253 g/cm3 and 0.17, respectively. The experimental batch adsorber used in this work is a cylindrical vessel with a capacity of 1.7 Liters of Basic Blue 3 dye solution. It can be agitated at different speeds using a 4-blade 45 deg. turbine and has a jacket surrounding the vessel to control the temperature. After adding 7 g clay, samples (5 ml) were taken during the batch adsorption experiments for analysis of aqueous dye concentration. Data from these experiments were used to determine the equilibrium isotherms and to determine the kinetics of the adsorption process as a function of various experimental parameters. The adsorption process apparently reached equilibrium after about three hours, although the kinetic experiments were done for six hours to assure that the adsorption process had reached true equilibrium under the different experimental conditions. The experimental fixed-bed adsorber set-up used in this work consists of a cylindrical tube with an internal diameter of 2.3 cm containing a packed bed of bentonite clay. A non-linear pore diffusion model was used to describe the adsorption process. This model can have nonlinear adsorption isotherms and two resistances, namely, an external mass transfer resistance with an internal mass transfer resistance (pore diffusion). The following assumptions were applied to the pore diffusion model: 1-The distribution of dye concentration in the solution surrounding a clay particle is uniform. 2-The shape of the clay particle can be represented as a sphere. 3-The diffusion coefficient is constant 4-Dye diffusion occurs only along the radial- axis of the spherical clay particle. In order to predict the breakthrough curve for the fixed adsorption bed when external mass transfer and pore diffusion resistances are assumed to control the adsorption rate, the dimensionless mass balance equation for the bed needs to be solved simultaneously with the non-linear pore diffusion model equations given above at every column height. The "method of lines" was used to convert a partial differential equation into a set of ordinary differential equations. Specifically, the partial differential equations were converted into a set of ordinary differential equations with specified initial values by discretizing the spatial derivative using a stable and accurate finite difference scheme. In the case of the batch adsorber, after converting the partial differential equation into a system of ordinary differential equations with specified initial values, the system was solved using ODE15s solver from MATLAB. In the case of the fixed bed adsorber, after converting the partial differential equation into a system of ordinary differential equations with specified initial values, the system was solved using the subroutine SDRIV2, an integrator which uses the Adams method for the non-stiff ordinary differential equations, and the Gear method for stiff ordinary differential equations. The comparison between the theoretical predictions from the Langmuir, Freundlich and Redlich-Peterson models and experimental equilibrium data showed adjusted coefficients of determination, R2 adjusted = 0.964, 0.941, and 0.967 respectively. Because the adjusted coefficients of determination for all of the isotherms were quite close to one, only slight differences in the goodness of fit existed between these models. Because the Langmuir isotherm seemed to predict better the adsorption capacity of clay for the dye, it was used to describe the equilibrium in the adsorber modeling calculations. The external mass transfer coefficient was found from the initial batch adsorption data to be approximately 0.0003 m/sec. The effective pore diffusion coefficient was found to be 31.0e-9 m2/sec for an initial dye concentration of 183 ppm and this value decreased by more than an order of magnitude as the initial dye concentration was increased to 1427 ppm. Generally the predictions from

the model agreed well with the experimental batch adsorption data. The pore diffusion coefficient and the equilibrium parameters determined from the batch adsorption data were used to predict the breakthrough curves for the adsorption of Basic Blue 3 dye by Saudi bentonite clay in the experimental fixed bed adsorber. The predicted breakthrough curves from the fixed bed pore diffusion model did not agree with the experimental data. The inconsistency between the data and the predictions can be attributed to clumping of the clay and channeling in the fixed bed.