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TECHNICAL NOTE

Decolorizing Wastewater in a Fixed Bed Using Natural Adsorbents

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ABSTRACT

The possibility of using sawdust as an adsorbent in a fixed-bed adsorber in decolorizing wastewater as well as batchwise was studied. The Freundlich isotherm was obtained for the adsorption of a basic dyestuff (Maxillon Blue) on wood. The factors studied under isothermal adsorption conditions include feed input velocity, wood particle size, and bed height. The controlling step of adsorption at relatively high velocities is the internal diffusion within the pores rather than the external diffusion. The results showed that the best operating conditions were obtained at an intermediate feed velocity of 0.12 cm/s, a particle diameter of 0.018 cm, and a bed height of 10 cm.

INTRODUCTION

The removal of colors and impurities is of increasing industrial importance. Activated carbon is the most widely used material for decolorizing wastewaters. Other materials have been studied for dye removal (1–5). Fuller's earth and bauxite were found to be successful as adsorbents for color removal on a laboratory scale, but considerable flow problems were encountered in a fixed-bed system. McKay et al. (6) investigated the removal of basic Astrazone Blue from effluents using silica gel as an adsorbent. Investigations by McKay et al. (2) were made to determine whether cheap, commercially available materials hold promise in the treatment of wastewater. Their initial findings indicated that peat wood has a high adsorptive capacity for dyes and is relatively cheap. The cheapness of

the adsorbent means that regeneration is not necessary and the spent adsorber can be burned. The batch adsorption process is usually limited to the treatment of small volumes of effluent, whereas a fixed-bed flow system has an advantage because the solute concentration is changing continuously while the solute is being adsorbed. In this paper many factors affecting adsorption rates and breakthrough curves for the aqueous solution of a basic dyestuff (Maxillon Blue) were studied in a batchwise and semicontinuous fixed-bed adsorber. The mass transfer zone, the effective efficiency of the mass transfer zone, the length of unused bed, and the dynamic capacity of the adsorbent were determined by using the Michaels approach (7). The controlling rate was also determined.

EXPERIMENTAL

Adsorption Isotherm

Equilibrium adsorptions at 27°C and 1 atm were conducted by mixing a known quantity of sawdust into a measured volume of dye solution at different concentrations. The solutions were shaken continuously for 3 days to reach equilibrium before being analyzed.

Rate Data

The adsorbate (500 cm^3) with a concentration 0.1 g/L was mixed with 5 g adsorbent. The beaker was provided with an electrical stirrer operating at 500 rpm. Samples were withdrawn successively from the same mixture at different time intervals for analysis. The withdrawn samples were filtered and analyzed spectrophotometrically (Milton Roy1201).

Fixed-Bed Adsorber

The feed stream was poured through a fixed bed of wood sawdust at three different feed velocities (0.75, 0.12, and 0.064 cm/s) with a feed concentration of 0.1 g/L into three different bed heights (2, 5, and 10 cm). Three different particle sizes were used (0.6, 0.25, and 0.18 mm). Samples of the effluent solution were withdrawn at different times and analyzed spectrophotometrically.

RESULTS AND DISCUSSION

Isotherm

Over the concentration range used for the rate runs, the adsorption isotherm data could be fitted accurately to a Freundlich isotherm of the

form

$$q = 0.036C^{0.1136}$$

where q = solid-phase concentration (mg/g)
c = liquid-phase concentration (mg/g)

Adsorption Rate

It has been found that the adsorption rate is not affected by the speed of mixing, which means that intraparticle diffusion is the controlling resistance rather than the external diffusion. The values of the intraparticle diffusion coefficient D_i were obtained from the equation of Urano and Nakai (8). According to Fig. 1, the value of D_i is 6.28×10^{-6} cm^2/s at a liquid concentration of 10 mg/L.

Breakthrough Curves

The breakthrough curves were measured for various values of particle diameter, liquid flow rate, and packed bed height. These runs were conducted at an adsorption temperature of 27°C. The effect of three different

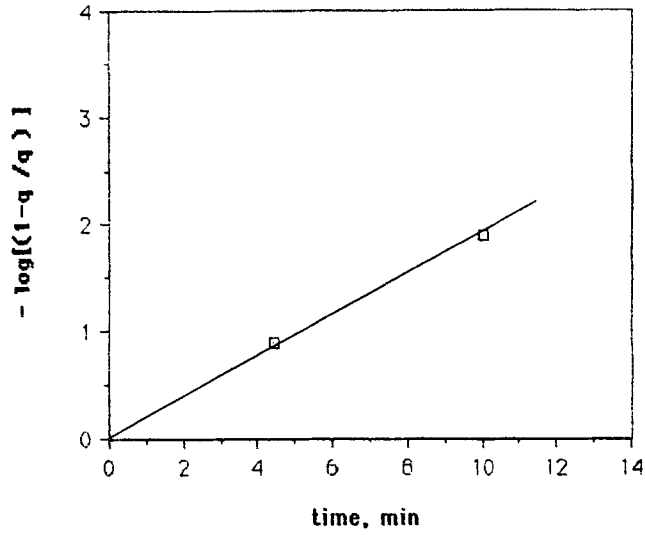

FIG. 1 Adsorption rates of Maxillon Blue in batch tests.

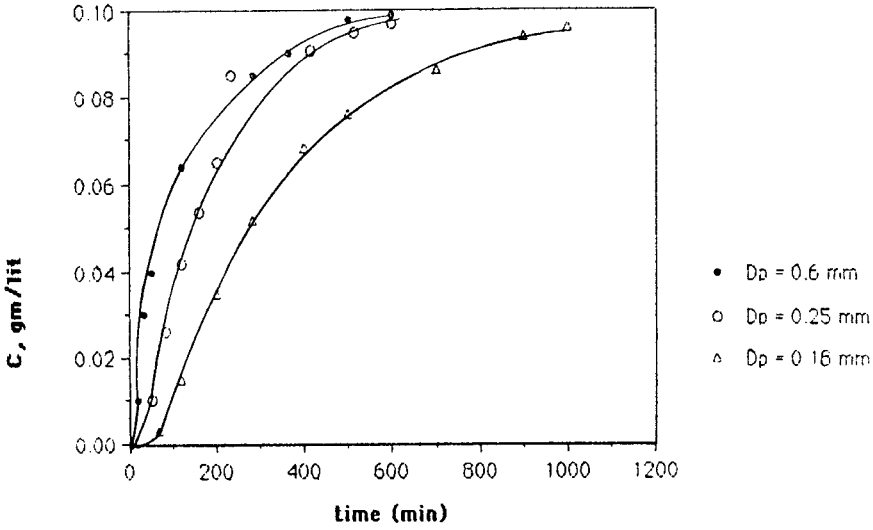

FIG. 2 Effect of sawdust particle size on breakthrough curves at velocity = 0.12 cm/s and height of the adsorption column = 5 cm.

particle sizes (0.6, 0.25, and 0.18 mm) on the breakthrough curve at a feed velocity of 0.175 cm/s and a bed height of 5 cm is shown in Fig. 2. As seen from Table 1, the particle size of 0.18 mm gave the best results. For this particle size the mass transfer zone (MTZ) and the length of unused bed (LUB) were the smallest, and the effective efficiency of the mass transfer zone (E) and the dynamic capacity (DC) were the largest when compared to the other particle sizes. It is clear that the break time (TB) is shortened when the particle size is increased.

TABLE 1
Size Effect on the Dynamic Adsorption Parameter (v = 0.12 cm/s, z = 5 cm)

d^a (mm)	MTZ (cm)	LUB (cm)	TB (min)	E%	DC (g/g)
0.60	6.660	3.53	20	0.294	23.04
0.25	5.745	3.33	40	0.334	23.76
0.18	2.870	2.73	100	0.454	46.80

[a] d = diameter of adsorbent (mm).

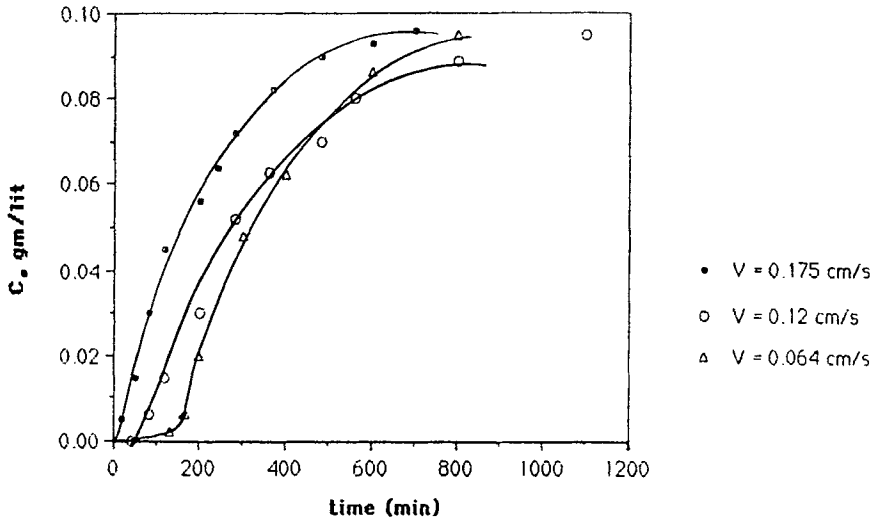

FIG. 3 Effect of velocity on the breakthrough curves at particle size = 0.018 cm and height of the adsorption column = 5 cm.

The effect of three different feed velocities (0.175, 0.12, and 0.064 cm/s) at a bed height of 5 cm and a particle size of 0.018 cm is shown in Fig. 3. It is clear that the break time is shortened when the velocity is increased. At low velocities the adsorption rate is controlled by external diffusion. By increasing the feed velocity, the controlling step of adsorption becomes internal diffusion within the pores. Table 2 shows the effect of feed velocity on the dynamics of adsorption. It indicates that at an intermediate feed velocity of 0.12 cm/s, minimum MTZ and maximum effective efficiencies

TABLE 2
Feed Velocity Effects on the Dynamics of Adsorption (d = 0.18 mm, z = 5 cm)

v (cm/s)	MTZ (cm)	LUB (cm)	TB (min)	E%	DC (g/g)
0.175	5	3.67	40	0.266	47.25
0.12	2.871	2.73	100	0.454	55.44
0.064	2.595	2.273	170	0.454	20.35

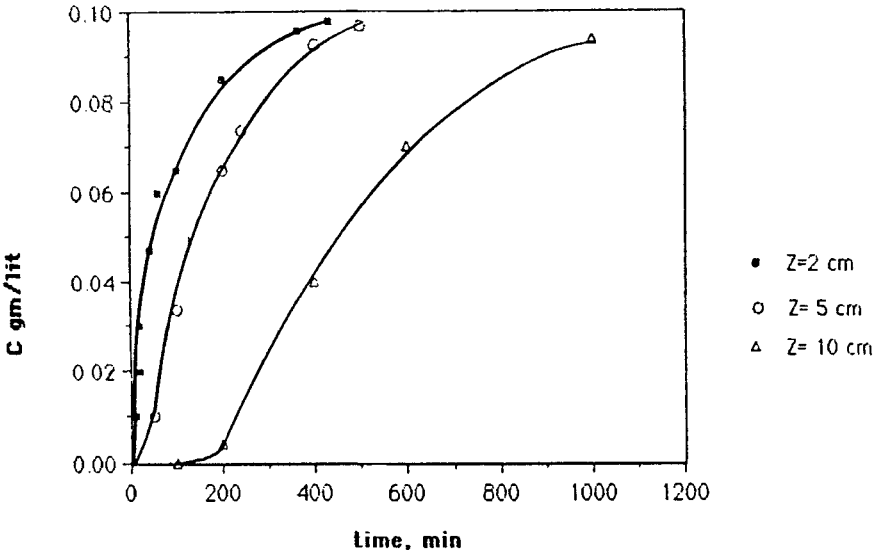

FIG. 4 Effect of bed height of particle size = 0.25 mm and velocity = 0.12 cm/s.

of the mass transfer zone and the dynamic capacity of the adsorbent were obtained.

Figure 4 illustrates the effect of three bed heights (2, 5, and 10 cm) on the breakthrough curves, and it indicates that the break time is shortened at a shorter bed height. Correspondingly, the break time is increased by increasing the bed height. Table 3 shows the effect of bed height on the dynamics of adsorption. It is clear from Table 3 that as the height of the bed increases, MTZ decreases; in contrast, E% and DC increase.

TABLE 3
Effect of Bed Height on the Dynamics of Adsorption (d = 0.25 mm, v = 1.2 cm/s)

Z (cm)	MTZ (cm)	LUB (cm)	TB (min)	E%	DC (g/g)
2	5.95	1.714	10	0.143	4.320
5	5.745	3.530	40	0.294	22.04
10	5.357	5.090	260	0.491	23.32

CONCLUSION

A fixed-bed adsorber succeeded in decolorizing wastewater by using sawdust as a natural, cheap adsorbent. The best purification conditions were obtained at an intermediate feed velocity, a small particle size, a and long bed height. MTZ was significantly minimized, and the efficiency of the mass transfer zone and the dynamic capacity of the adsorbent were maximized.

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