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Kinetics of Pyridine Adsorption onto Granular Activated Carbon

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1. Introduction

Pyridine is an organic and toxic liquid. It is used as a solvent in paints and an intermediate in the manufacture of insecticides and herbicides, vitamins, dyes, drugs and adhesives. Pyridine and its derivates have shown to be very hazardous to aquatic life and human beings [1]. Several methods have been developed for the removal of pyridine from wastewater such as biodegradation, photodegradation, ozonation and adsorption. Adsorption has been shown to be very effective.

The adsorption of pyridine on activated carbon has been studied in few works and it has been found that pyridine can be effectively removed from water solutions by adsorption on granular activated carbon (GAC) [2]. However, the overall rate of adsorption of pyridine on GAC has not been studied and the mass transport mechanisms that control the overall rate of adsorption have not been elucidated. The overall rate of adsorption can be interpreted with the diffusional model proposed by Leyva-Ramos and Geankoplis [3]. This diffusional model includes adsorption rate on an active site, pore volume diffusion, surface diffusion, and external mass transfer. The model equations are:

$$V\frac{\mathrm{d}C_A}{dt} = -mSk_L\left(C_{\mathrm{A}} - C_{\mathrm{Ar}}\Big|_{r=R}\right) \qquad t=0,\ C_{\mathrm{A}} = C_{\mathrm{A0}}$$

$$\varepsilon_p\frac{\partial C_{\mathrm{Ar}}}{\partial t} + \rho_p\frac{\partial C_{\mathrm{Ar}}}{\partial t} = \frac{1}{r^2}\frac{\partial}{\partial r}\left[r^2\left(D_{ep}\frac{\partial C_{\mathrm{Ar}}}{\partial r} + D_s\rho_p\frac{\partial q}{\partial r}\right)\right] \qquad t=0,\ C_{\mathrm{Ar}} = 0,\ \ 0\le r\le R$$

$$\left.\frac{\partial C_{\mathrm{Ar}}}{\partial t}\right|_{r=0} = 0; \qquad \left.D_{ep}\frac{\partial C_{\mathrm{Ar}}}{\partial r} + D_s\rho_p\frac{\partial q}{\partial r}\right|_{r=R} = k_{\mathrm{L}}\left(C_{\mathrm{A}} - C_{\mathrm{Ar}}\Big|_{r=R}\right)$$

The aim of this work is to interpret the adsorption rate of pyridine on GAC with a diffusional model and to elucidate the intraparticle diffusion mechanisms controlling the rate of adsorption.

2. Experimental Methods

The GAC used in this work is Filtrasorb 400, which is manufactured by Calgon, Corp. The physicochemical and textural properties of GAC are: surface area = 925 m^2/g, void fraction = 0.554, pore volume = 0.534 cm^3/g and particle density = 1.036 g/cm^3. The concentration of pyridine in the aqueous solution were determined by UV spectroscopy using a spectrophotometer, Shimadzu, model UV-160 at a wavelength of 249.5 nm.

The concentration decay curves were obtained using a rotating basket adsorber of 1 L. The solution was sampled periodically until equilibrium was reached. The samples were

analyzed by UV spectroscopy and the dimensionless concentration ϕ_A (C_A/C_{A0}) was plotted against time to obtain the dimensionless concentration decay curve. The concentration decay curves were fitted using the diffusional model to obtain the best value of the effective pore volume diffusivity, D_{ep}, or surface diffusion coefficient, D_s.

3. Results and Discussion

The diffusional model was solved assuming that pore volume diffusion is the controlling mechanism and the effective diffusion coefficient was estimated to be $D_{ep} = 1.22\times10^{-6}$ cm^2/s using a tortuosity value of 3.5 for GAC [3]. Figure 1 shows that using this value of D_{ep} the diffusional model did not fit the experimental data. The best value of D_{ep} that fitted the experimental data was $D_{ep} = 4.08\times10^{-5}$ cm^2/s. This value is five times greater than molecular diffusion coefficient ($D_{AB} = 0.77\times10^{-5}$ cm^2/s) and it is not possible since the effective diffusion coefficient has to be smaller than molecular diffusion coefficient. Figure 2 shows that the diffusional model assuming that the surface diffusion is the controlling mechanism fitted reasonably well the experimental data. The latter suggests that the surface diffusion plays a very important role on the adsorption rate of pyridine on GAC. The dependence of surface diffusion coefficient (D_S) on the mass of pyridine adsorbed, temperature, particle size and agitation speed were also investigated in this work.

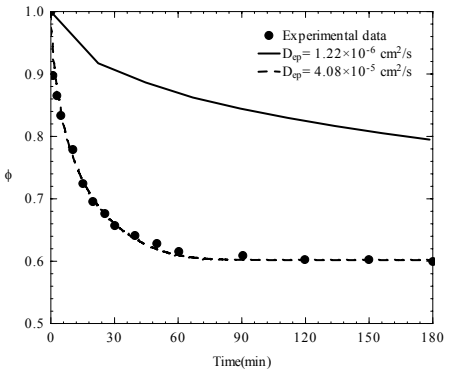

Fig. 1: Concentration decay curve of pyridine on CAG predicted with the pore volume diffusion model.

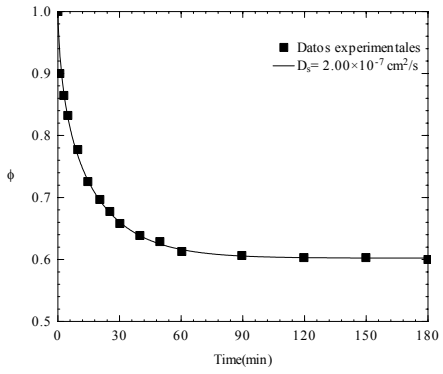

Fig. 2: Concentration decay curve of pyridine on CAG predicted with the superface diffusion model.

4. Conclusions

The surface diffusion is the intraparticle diffusion mechanism controlling the overall rate of adsorption of pyridine on GAC. The surface diffusion coefficients were estimated from the concentration decay curves and were found to depend on the mass of fluoride adsorbed and the temperature.

References

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[3] R. Leyva-Ramos, C. J. Geankoplis, Can. J. Chem. Eng. 72 (1994) 262-271.