

# A NEW RATE MODEL FOR THE OXIC REMOVAL OF PHENOL AND o-CRESOL BY GRANULATED ACTIVATED CARBON:

## II. COLUMN STUDIES

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### Introduction

Phenolic compounds, on adsorption on granular activated carbons(GAC) in the presence of oxygen, react to form dimers and trimers etc. which are irreversibly adsorbed(1,2). The driving force for the transport of the organics into the GAC is the chemical potential and the flux is observed to be a dual mechanism of surface diffusion and pore diffusion(3). In a previous presentation, we reported the adsorption and reaction in the particle(4). Here we extend the results to column studies.

### Experimental

A packed column (60 cm long and 2.54 cm I. D.) is loaded with 130 gms of Filtrasorb-400 GAC particles (size, 0.156 cm). The activated carbon columns were operated in an upflow mode at a flow rate of 100 ml/min resulting in 0.197 m/min (superficial velocity) at room temperature with a feed concentration of 70 mg/l. Anoxic experiments were performed by purging the feed solution with nitrogen and subsequently storing the solution under a head space of nitrogen Yet a dissolved oxygen concentration 0.04-0.4 mg/l. could still be detected. The oxic column experiments were performed by purging the adsorbate solution with pure oxygen until saturation was reached and a DO concentration of 30 mg/l was measured.

### Theoretical

Assuming axial dispersed plug flow for the column, combined pore and surface diffusion under a chemical potential gradient for the

organics in the particles, surface diffusion for oxygen, Langmuir-Freundlich isotherms, and irreversible adsorption of the dimers, the model equations are:

Fluid phase balances:

$$-D_L \frac{\partial^2 c_A}{\partial z^2} + v \frac{\partial c_A}{\partial z} + \frac{\partial c_A}{\partial t} + \left( \frac{1-\epsilon}{\epsilon} \right) \frac{\partial \bar{q}_A}{\partial t} = 0$$

$$-D_L \frac{\partial^2 c_B}{\partial z^2} + v \frac{\partial c_B}{\partial z} + \frac{\partial c_B}{\partial t} + \left( \frac{1-\epsilon}{\epsilon} \right) \frac{\partial \bar{q}_B}{\partial t} = 0$$

Particle mass balances are

$$\frac{\partial q_A}{\partial t} = \frac{1}{r^2} \frac{\partial}{\partial r} \left\{ r^2 \left[ \epsilon_P \frac{D_{PA}}{\rho_P} \frac{\partial c_A}{\partial r} + D_{AS} \right] \frac{\partial q_A}{\partial r} \right\}$$

$$+ R_A$$

$$\frac{\partial q_B}{\partial t} = \frac{D_{BS}}{r^2} \frac{\partial}{\partial r} \left\{ r^2 \frac{\partial q_B}{\partial r} \right\} + R_B$$

$$\frac{\partial q_C}{\partial t} = R_C$$

where the rate of reaction is given by:

$$R_C = k_r \theta_A \theta_B \text{ and}$$

$$R_A = \gamma_A / \gamma_C R_C M_A / M_C$$

$$R_B = \gamma_B / \gamma_C R_C M_B / M_C$$

and  $\gamma_i$  are the stoichiometric coefficients, positive for products, negative for reactants, and zero for inerts. The isotherms are given by

$$\theta_A = \frac{q_A}{q_{sat}} = \frac{k_A C_A^{1/n_A}}{1 + k_A C_A^{1/n_A} + k_B C_B + k_C C_C^{1/n_C}}$$

$$\theta_B = \frac{q_B}{q_{sat}} = \frac{k_B C_B}{1 + k_A C_A^{1/n_A} + k_B C_B + k_C C_C^{1/n_C}}$$

$$\theta_C = \frac{q_C}{q_{sat}} = \frac{k_C C_C^{1/n_C}}{1 + k_A C_A^{1/n_A} + k_B C_B + k_C C_C^{1/n_C}}$$

It should be noted that although  $c_A$  and  $c_B$  exist in the liquid phase in the oxic system, no trace of component C has ever been observed to desorb from the solid phase in the aqueous system. Hence no fluid phase mass balance is included for this species.

These equations were solved using the following boundary conditions (Danckwerts):

$$-D_L \frac{\partial c_A}{\partial z} \Big|_{0^-} = v(c_A|_{0^-} - c_A)$$

$$-D_L \frac{\partial c_B}{\partial z} \Big|_{0^-} = v(c_B^*|_{0^-} - c_B)$$

$$\frac{\partial c_A}{\partial z}(L, t) = 0; \quad \frac{\partial c_B}{\partial z}(L, t) = 0.$$

$$\frac{\partial \bar{q}_A}{\partial t} = \frac{3k_f}{\rho_p R_p} (c_A(R_p, t) - c_A(z, t))$$

$$\frac{\partial \bar{q}_B}{\partial t} = \frac{3k_f}{\rho_p R_p} (c_B(R_p, t) - c_B(z, t))$$

$$\frac{\partial q_A(0, t)}{\partial r} \Big|_{r=0} = 0; \quad \frac{\partial q_B(0, t)}{\partial r} \Big|_{r=0} = 0$$

$$\bar{q}_A = \frac{3}{R_p^3} \int_0^{R_p} r^2 q_A dr$$

$$\bar{q}_B = \frac{3}{R_p^3} \int_0^{R_p} r^2 q_B dr$$

The initial conditions are:

$$q_A = q_C = 0.0, \quad q_B = q_{BO}; \quad c_A = 0, \quad c_B = c_{BO}$$

$$c_c = 0$$

## Results and Discussion

The equations given above are presently being solved using the orthogonal collocation method. The experimental results for phenol and o-cresol breakthrough, presented in Figures 1 and 2, show that the oxic breakthrough curves are much slower than the anoxic. From these curves we expect to report the reaction rate constant.

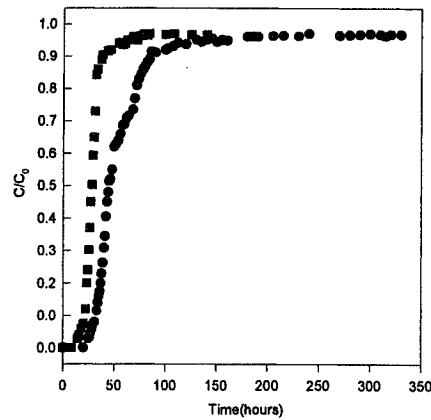


Figure 1. Phenol breakthrough Curves - Oxic

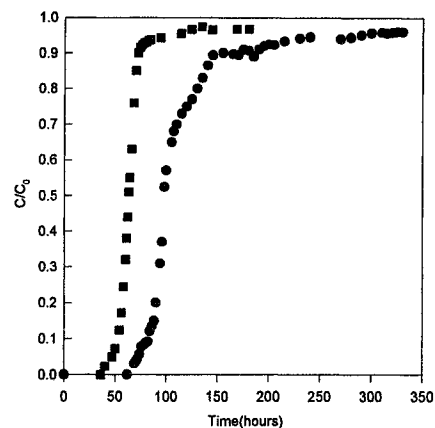


Figure 2. o-Cresol Breakthru Curves- Oxic

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