Mass Transfer Studies on Fluidized Bed Adsorption Column for Phenol Adsorption

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Abstract: ***Mathematical modeling for removal of Phenol using fluidized bed adsorption from the wastewater has been presented in this work. Present experimental study deals with effect of initial concentration of phenol and particle size on the rate of adsorption. The fluid and solid phase mass transfer coefficient at various mass of phenol in the solvent per unit mass of adsorbent were found in well agreement with well known mathematical models. It is observed that the fluid phase and solid phase mass transfer coefficients increases with increase in initial phenol concentration and decrease in particle size. Maximum value of mass transfer coefficient was realized at higher phenol concentration and minimum particle size.***

Keywords: Fluidized bed adsorption, Mathematical modeling, mass transfer coefficient, particle size as

1. Introduction

Adsorption of pollutants is very effective method for waste pollution control. Adsorption depends on various parameters like initial pheonol concentration, pH, and adsorbent dose. The studies on mass transfer coefficient are very important because of its significance in the adsorption process. The adsorption process for charcoal follows closely Freundlich isotherm. So chemisorption dominates the physical adsorption. Adsorption of phenol from aqueous solutions using activated carbons from Tectona grand is sawdust has been tried by Mohanti et al. [1]. The bubble column studies for the phenols removal from waste water have been carried out by Kumar et al. [2]**.** Fluidization, its advantages and other aspects are described by Leva[3]. Coony and Zhenpeng Xi, have observed that activated carbon catalizes reaction of phenolics during liquid phase adsorption [4].

1.1 Fluidization

Owning to the intense agitation in a well fluidizing dense phase bed, local temp and solid distribution are much more uniform than in the fixed bed. This may be important in many chemical and catalytic processes. Since in a fluidized bed particle size of a smaller order of magnitude than in the fixed bed, the resistance to diffusion through the particles is smaller in the fluidized bed. This too may benefit many chemical and catalytic reactions. Fluidization will permit the ready additions of solids to or the withdrawals of solids from the bed. This is an important advantage over the fixed bed, especially where rapid activity losses are involved. This property of the fluidized bed system is responsible for the ease with which continuous operation is achieved.

2. Methodology

2.1 Preparation of adsorbent

There are various materials from which we can manufacture charcoal. In our case we used tamarind beans for the manufacture of charcoal. The tamarind beans were first clean to avoid the presence of mud on it. Fixed batch of tamarind beans were allowed to stay in heating furnace where the temperature was maintained at about 250 – 275oC. The furnace used is digitally controlled. So we get accurate temperature required for the preparation of charcoal. The tamarind beans were allowed to stay in furnace till red hot. Thus fixed batch of tamarind were taken out according to our requirement. The red hot tamarind was allowed to cool for some time till it reached the room temperature. Thus the tamarinds completely burned were crushed using jaw crusher. As according to our requirement the jaw crusher was adjusted. Thus the material after crushing was send to sieve analysis.

2.2 Details of Experimental Setup

The experimental setup used is shown in fig. 1. Fluidized bed of diameter 5.3 cm and total bed height of 22.5cm, having a screen at the bottom to support the charcoal and at the top to remove the presence of charcoal particles in the effluent. The top portion of the fluidized bed is detachable, for moving or addition of charcoal. The phenolic waste liquid from the phenolic waste tank is sent to the fluidized bed reactor with the help of the rotameter. Phenol concentration in the effluent obtained after treatment with charcoal at different time intervals were collected from the top of the fluidized bed. The monometer is connected to the fluidized bed from the bottom and top connection. For every run the pressure drop is obtained

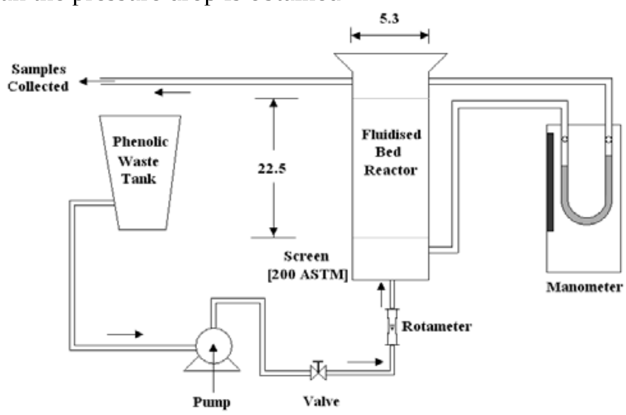

Figure 1: Schematic diagram of experimental set up

2.3 Experimental Procedure

Due to the non-availability of consistently of uniform waste samples, synthetic phenol wastes of different concentrations were made. The initial concentration of Phenol in the waste sample was varied from 200mg/lit to 300mg/lit for different runs. For studying the effect of particle size, the runs were taken at the particle size of 0.42 mm, 0.81 mm and 1.68 mm, keeping the initial phenol concentration constant. The Inlet flow rate was maintained constant at 3.84 lpm for various runs. The outlet concentration after three minutes interval was determined till there is no change in it.

2.4 Develpoment of Mathematical Model

Fig.2 shows the Material balance across the fluidized bed. The following assumptions were made for development of model as proposed by David and Zhenpeng [4].

- C is constant in a cross-sectional area
- The perfect mixing of solid occurs therefore q doesn't vary with position is function of time (t).
- For a short interval of time a quasi stationary regime is developed and therefore C is only function of L.
- The adsorption corresponds to a Langmuir adsorption isotherm Eq.(1)

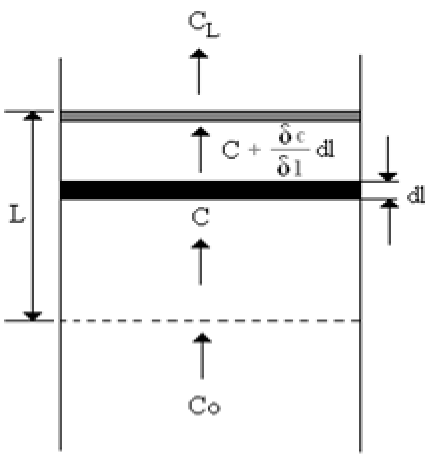

Figure 2: Material balance for the fluidized bed

Present experimental data were fitted with Eq. (1) and constants a' and b' were determined using Least square regression analysis and Presented in Fig: 1.

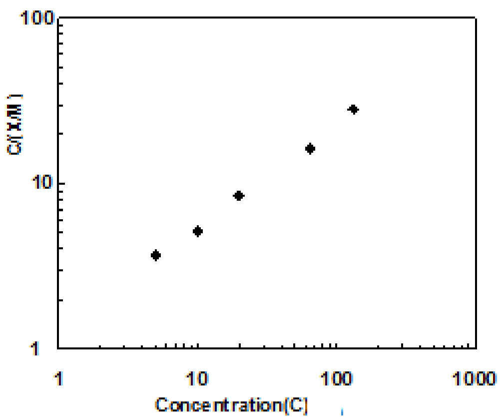

Figure 3: Validation of Langmuir adsorption isotherm.

$$\frac{C}{q} = \mathrm{b'.C + a'} \quad (1)$$

Langmuir adsorption isotherm was validated and presented in Eq. (3)

$$\frac{C}{q} = 0.188.\mathrm{C} + 2.719 \quad (2)$$

The variation of concentration of phenol to the adsorbent (q)with respect to time was calculated from Eq. (3)

$$\frac{dq}{dt} = \frac{F}{M}\left[C_o - C_L\right] \quad (3)$$

Integrating Eq.(3)between the limit t to(t+Δt), q changes from intial value at t to its values at time (t+Δt).

$$q(t+\Delta t) = q(t) + \frac{F}{M}\left[C_o - C_L\right]\Delta t \quad (4)$$

Fluid phase Mass transfer coefficient was calculated from Eq.(5)

$$K_{favg} = \frac{F}{S_L}\ln\left(\frac{C_o - C}{C_L - C}\right) \quad (5)$$

Solid phase internal mass transfer coefficient was calculated from Eq.(6)

$$K_{pavg} = \frac{F}{M}\cdot\frac{\mathrm{b'}}{(1-\mathrm{b'q})}\left[C_o - C\right] + \frac{\mathrm{a'}}{(1-\mathrm{b'q})^2}.\ln\left(\frac{\left(C_o - \frac{\mathrm{a'q}}{1-\mathrm{b'q}}\right)}{\left(C_L - \frac{\mathrm{a'q}}{1-\mathrm{b'q}}\right)}\right) \quad (6)$$

3. Results and Discussion

The result and discussion are presented in this section. Fig. 4 presents the variation of fluid phase mass transfer coefficient with mass of phenol in the solvent per unit mass of adsorbent at different phenol concentration. It is observed from this figure that as q increases fluid phase mass transfer coefficient decreases. It is also seen from this figure that at given q, fluid phase mass transfer coefficient observed maximum for high concentration of phenol. This may be due to fact that at high concentration favors the high rate of diffusion.

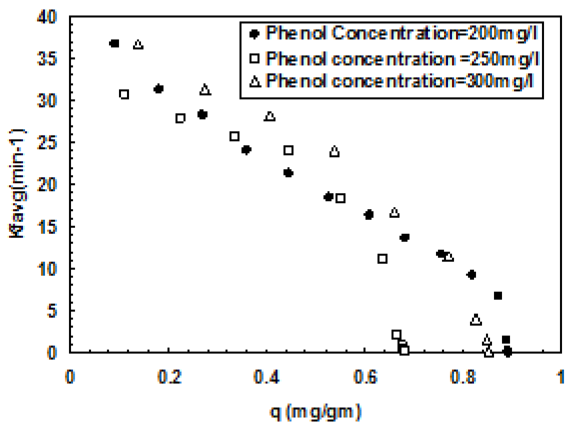

Figure 4: Variation of K_{favg} with q of different phenol concentration

Fig. 5 presents the variation of solid phase mass transfer coefficient with mass of phenol in the solvent per unit mass of adsorbent at different phenol concentration. It is observed from this figure that as q increases solid phase mass transfer coefficient decreases. It is also seen from this figure that at given q, solid phase mass transfer coefficient observed maximum for high concentration of phenol. This may be due to fact that at high concentration favors the high rate of diffusion.

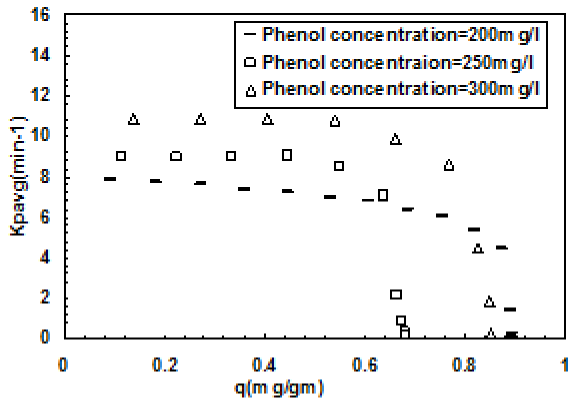

Figure 5: Variation of K_{pavg} with q of different phenol concentration

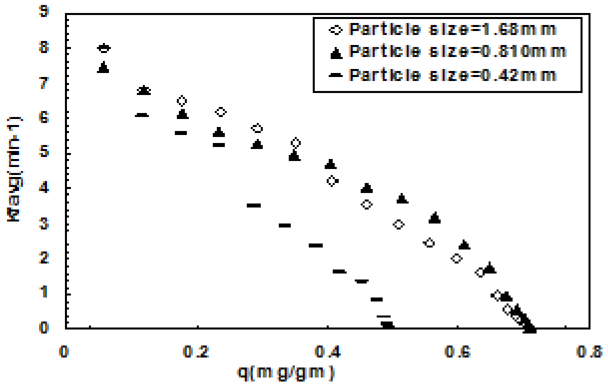

Figure 6: Variation of K_{favg} with q of different particle size

Fig. 6 presents the variation of fluid phase mass transfer coefficient with mass of phenol in the solvent per unit mass of adsorbent for different particle size. It is observed from this figure that as q increases fluid phase mass transfer coefficient decreases. It is also seen from this figure that at given q, fluid phase mass transfer coefficient observed maximum for lower particle size. This happens due to fact that for low particle size offers more surface area and ultimately increases diffusion of phenol on adsorbent.

Fig. 7 presents the variation of solid phase mass transfer coefficient with mass of phenol in the solvent per unit mass of adsorbent for different particle size. It is observed from this figure that as q increases solid phase mass transfer coefficient decreases. It is also seen from this figure that at given q, solid phase mass transfer coefficient observed maximum for lower particle size. This happen due to fact that low particle size offers more surface area therefore that gives higher rate of diffusion.

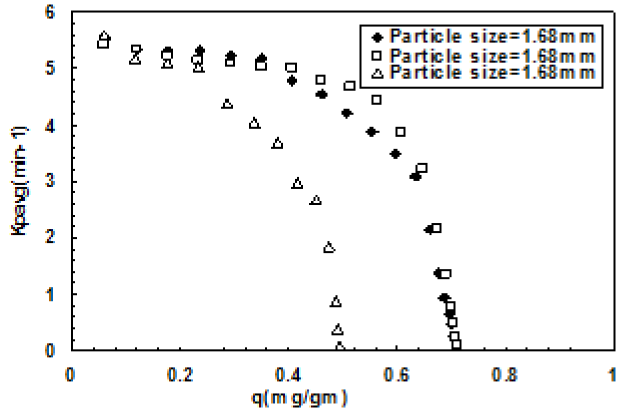

Figure 7: Variation of K_{pavg} with q of different particle size.

4. Conclusion

Present experimental investigation deals with mathematical modeling for Phenol removal using fluidized bed adsorption from the wastewater. The results are summarized as follows. It is observed that as q increases, fluid phase mass transfer coefficient decreases. It is also observed that at given q, fluid phase and solid phase mass transfer coefficients are maximum for the phenol concentration of 300 mg/l, owing to fact that high concentration favors the high rate of diffusion. It is also observed that as q increases fluid phase mass transfer coefficient decreases. It is also seen that at given q, fluid and solid phase mass transfer coefficient observed maximum for lower particle size 0.42 mm of owing to the fact that low particle size offers more surface area and ultimately increases diffusion of phenol on adsorbent.

5. Nomenclature

a', b'	Coefficients in adsorption isotherm
C	Phenol concentration mg/l
C_o	Initial phenol concentration mg/l
C_L	Concentration of phenol in fluid phase mg/l
F	Volumetric flow rate cm^3/sec
K_f	Constant of Freundlich isotherm
K_{favg}	Fluid phase mass transfer coefficient cm /min
K_{pavg}	Solid phase mass transfer coefficient cm /min
l	Height of adsorbent inside the column
M	Mass of adsorbent gram
q	Concentration of phenol ,mg phenol/gm charcoal
S_L	Cross sectional area of column cm^2
X	Concentration of phenol in solid phase mg

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