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MODELING FOR PACKED BED PHENOL REMOVAL BY LOW COST ADSORBENT PREPARED FROM RICE HUSK

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ABSTRACT

Phenol removal by using packed bed by using low cost adsorbent is practical and efficient method for phenolic waste treatment. Low cost adsorbent prepared from locally available rice husk was used for experiments in packed column and effects of various parameters like initial concentration, flow rate and bed height on break through curve were studied. The experimental data was fitted in three models. Thomas, Yoon Nelson and Adam Bohart models were used for analyzing break through curves. The breaks through curves were best described by Thomas model followed by Yoon Nelson model and Adam Bohart model. It was also observed that various model parameters were affected by the factors like initial concentration, flow rate and bed height.

Key words: Adsorbent, Break through time, Exhaustion, Kinetic parameters.

INTRODUCTION

Adsorption is one of the important methods for removal of various pollutants from wastewater. Phenol is one such pollutant emitted from the various industrial sources like petroleum industries, pharmaceutical industries, resin manufacturing industries, dye synthesis units, pulp and paper mills. Packed bed adsorption can be used effectively for the removal of phenol from wastewater. Various investigators have used low cost adsorbents in batch experiments for studying the effects of various parameters like pH, initial concentration, adsorbent dose and particle size[1-4]. Studies have indicated that pH value in the range of 6 to 7 is optimum for phenol removal[5-7]. With initial concentration, the adsorption increases and remains constant at certain initial concentration. The optimum initial concentration varies with the adsorbent used. Increase in the adsorbent dose also increases the adsorption up to certain optimum adsorption dose. Small particle size favours adsorption due to increase in area[8-11].

It is important to select appropriate size because when particle size is very small, the slurry formation occurs and sites cannot be utilized completely for adsorption. Use of packed bed for adsorption is very efficient approach for practical application of the adsorption process. Studies have been reported on packed bed adsorption. The parameters affecting packed bed adsorption includes initial concentration, bed

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height, pH and flow rate[12-14]. Studies indicate that the nature of break through curve is affected by these parameters. With increase initial concentration and bed height break through time is reduces while it delays with bed height[16,17]. The models like Thomas-BDST (Bed Depth Service Time), Yoon-Nelson and Adam Bohart can be used for analyzing break through curve. The current investigation is aimed at studying effects of parameters like initial concentration, flow rate and bed height on the packed bed adsorption of phenol and application of these two models for explaining break through curves.

EXPERIMENTAL

Models for packed bed

Thomas – BDST Model based on Langmuir kinetics is expressed as follows[18,19].

$$\frac{C}{C_o} = \frac{1}{1+\exp\left[K_{\frac{T}{Q}(qM - CoV)}\right]} \quad ...(1)$$

$$\ln\left(\frac{C}{C_o} - 1\right) = \frac{K_T\, q_o\, M}{Q} - C_o \frac{K_T C_o}{Q} V \quad ...(2)$$

Where C, Co = The effluent and inlet solute concentrations (mg/L), q_0 = The maximum adsorption capacity (mg/g), M = The total mass of the adsorbent (g), Q = Volumetric flow rate (mL/min), V = The throughput volume (mL) and K_T = the Thomas rate constant (mL/min/mg). Yoon Nelson model is expressed as following equation[18,19].

$$\frac{C}{C_o} = \frac{1}{1+\exp\left[K\,(\tau - t)\right]} \quad ...(3)$$

$$\ln\frac{C}{C_o - C} = k\,t - \tau\,k \quad ...(4)$$

Here, k is the rate constant, t is time required for 50 percent adsorbate break through and t is sampling time. The Adams-Bohart model is used for the description of the initial part of the breakthrough curve. It is represented by following equation[20].

$$\frac{C}{C_o} = \exp\left(k_{AB}\, C_o\, t - k_{AB}\, N_o \frac{z}{uo}\right) \quad ...(5)$$

$$\ln\frac{C}{C_o} = k_{AB}\, C_o\, t - k_{AB}\, N_o \frac{z}{uo} \quad ...(6)$$

In this equation, k_{AB} (l/min.mg) is rate constant of Adams-Bohart model, z (cm) is the bed depth, N_0 (mg/L) is maximum ion adsorption capacity per unit volume of adsorbent column, and u_0 (cm/min) is the linear velocity of influent solution.

Methodology

Rice husk adsorbent was prepared from the rice husk from nearby Konkan area in Maharashtra near Mumbai. Rice husk was washed with first distilled water and then with concentrated hydrochloric acid and water. It was kept in oven at 150°C for 5 hrs. It was then thermally activated at 400°C. Packed bed glass columns of 5 cm diameter and 100 cm height were used for experiments. The influent was allowed to flow by gravity through the bed. The wire mesh was fixed at the bottom. The effluent collected from the outlet was analyzed by spectrophotometric method using U.V. spectrophotometer (ELICO 159). The pH was maintained at 5, the optimum value obtained in batch experiments.

RESULTS AND DISCUSSION

Experiments were carried out to study effect of various parameters like initial concentration, flow rate and bed height on break through curve. Three models namely Thomas-BDST model, Yoon Nelson model and Adam Bohart model were used for analyzing the break through curve. The break through time and exhaustion time behavior for different initial concentration, flow rate and bed height was studied.

Effect of initial concentration on breakthrough curve

Effect of initial concentration on break through curve is shown in Fig. 1. In the concentration range of 250 mg/L to 1000 mg/L, the break through time, considered as time required to reach 10% of initial concentration, was almost constant, though there was small increase in the breakthrough time from 17 mins to 22 mins for decrease in concentration from 1000 to 500 mg/L. The exhaustion time increased with decrease in initial concentration. At higher initial concentration the concentration gradient is more, which is driving force for mass transfer. Similar investigations have indicated that, with increase in initial concentration, the removal increases and exhaustion time decreases. The results obtained are in agreement with similar investigations carried out with different adsorbents[21,22].

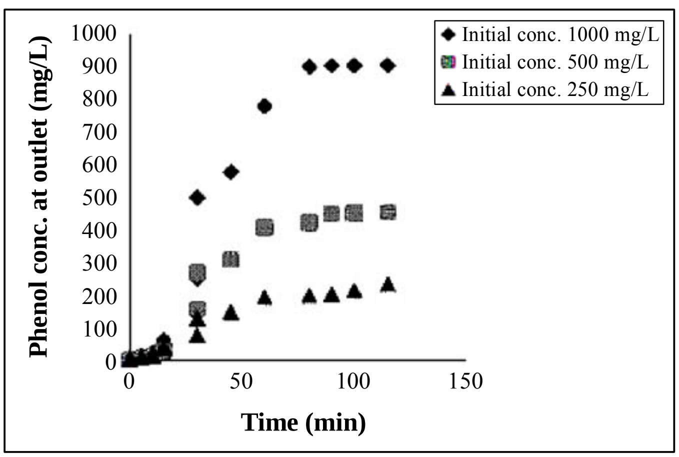

Fig. 1: Effect of initial concentration on breakthrough curve

The exhaustion times for initial concentrations of 1000 mg/L, 500 mg/L and 250 mg/L were 80, 92 and 100 mins, respectively. The value of C/C_0 was maximum for the lowest initial concentration 250 mg/L. With decrease in initial concentration, Thomas rate constant K_T increased from 0.076 mL/min/mg for 1000 mg/L to 0.308 mL/min/mg for 250 mg/L. Yoon Nelson constant k remained almost constant in the concentration range of 250 to 1000 mg/L. With decrease in initial concentration. Maximum adsorption capacity was maximum at 1000 mg/L and minimum for 250 mg/L. N_0 in Adam Bohart model decreased and k_{AB} increased. Faster saturation of adsorbent sites can be the reason for decrease in the N_0, the maximum ion adsorption capacity per unit volume of adsorbent column. The effect of initial concentration on model parameters and values of model parameters are shown Fig. 2 to 4. The model parameters are tabulated in Tables 1 to 3.

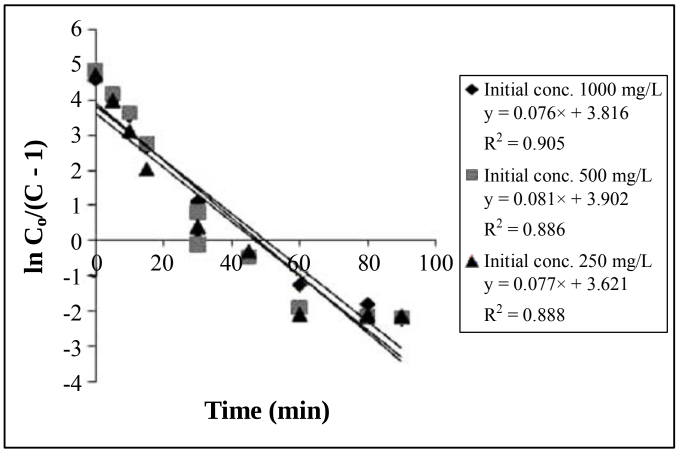

Fig. 2: Effect of initial concentration on Thomas-BDST model

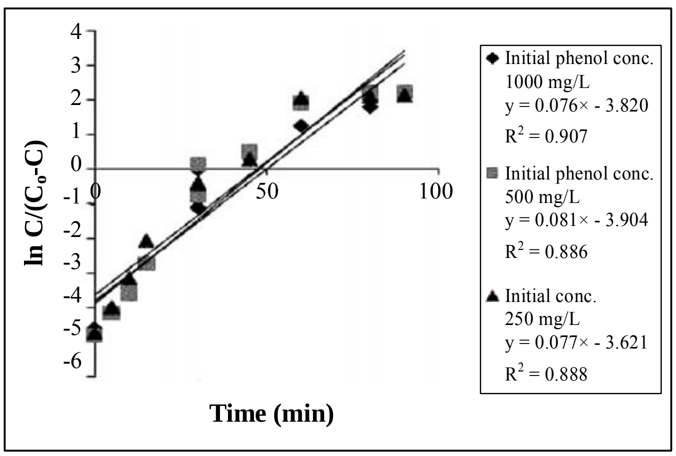

Fig. 3: Effect of initial concentration on Yoon Nelson model

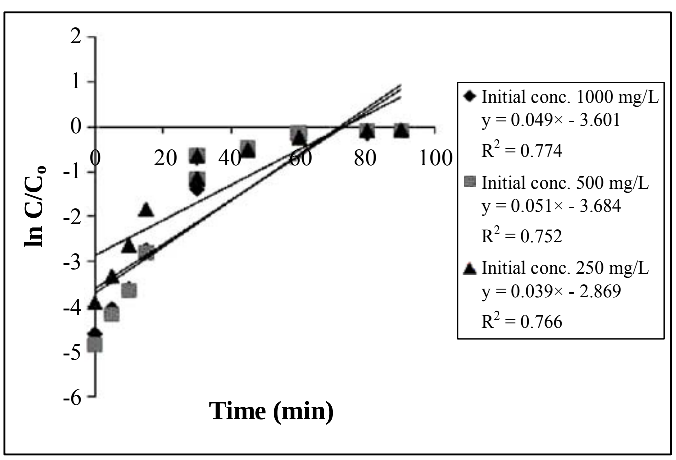

Fig. 4: Effect of initial concentration on Adams-Bohart model

Table 1: Effect of initial concentration for thomas model

Parameters	Initial concentration	At fixed bed height, pH and flow rate (mg/L)	
	1000	500	250
K_T (mL/min/mg)	0.076	0.162	0.308
q_0 (mg/g)	19.498	12.04	5.874
$_R2$	0.905	0.886	0.888

Table 2: Effect of initial concentration for yoon nelson model

Parameters	Initial concentration	At fixed bed height, pH and flow rate (mg/L)	
	1000	500	250
k(/min^{-1})	0.076	0.081	0.077
(min)	50.26	48.19	47
R^2	0.907	0.886	0.888

Table 3: Effect of initial concentration for adams-bohart model

Parameters	Initial concentration	At fixed bed height, pH and flow rate (mg/L)	
	1000	500	250
K_{AB} (mL/min/mg)	0.049	0.102	0.156
N_0 (mg/L)	3674.48	1806.8	919
$_R2$	0.774	0.752	0.766

Effect of flowrate

Effect of flow rate was studied with initial concentration of 1000 mg/L. The bed exhausted at faster rate for higher concentration. The exhaustion time for 80 mg/L was 45 mins while it was 90 min for 40 mg/L. The rapid availability of adsorbate can be the reason for this. Thomas rate constant increased with flow rate initially and then it was not affected by flow rate. Adsorption capacity q_0 increased with flow rate. Yoon Nelson kinetic constant increased with flow rate. Adam Bohart kinetic parameter K_{AB} indicated marginal increase. The N_0 value was almost constant with flow rate. Effect of flow rate is depicted in Fig. 5 to 8. Table 4 to 6 indicates the model parameters for different flow rates.

Table 4: Effect of flow rate for Thomas Model

Parameters	Flow rate (mL/min) at fixed bed height, initial concentration and pH		
	40	60	80
K_T (mL/min/mg)	0.067	0.083	0.081
q_0 (mg/g)	15.65	22.66	30.64
R^2	0.801	0.902	0.914

Table 5: Effect of flow rate for yoon nelson model

Parameters	Flow rate at fixed bed height, pH and initial concentration (mL/min)		
	40	60	80
k (/min^{-1})	0.067	0.083	0.081
(min)	42.059	45.32	45.96
R^2	0.801	0.902	0.914

Table 6: Effect of flow rate for adams-bohart model

Parameters	Flow rate at fixed bed height, pH and initial concentration (mL/min)		
	40	60	80
K_{AB} (mL/min/mg)	0.082	0.089	0.088
N_0 (mg/L)	2362	2358.4	2388.63
R^2	0.738	0.8	0.816

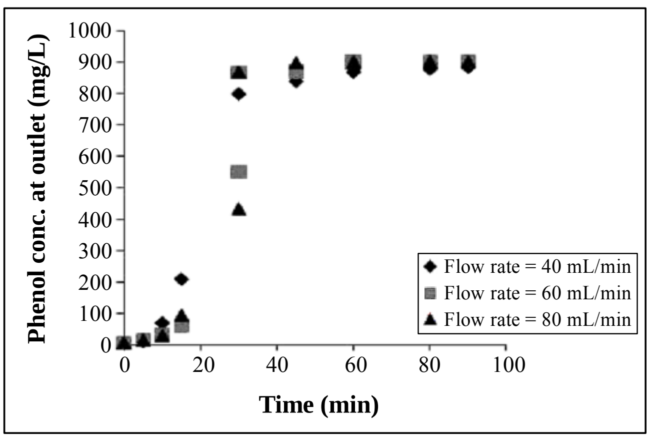

Fig. 5: Effect of flow rate on breakthrough curve

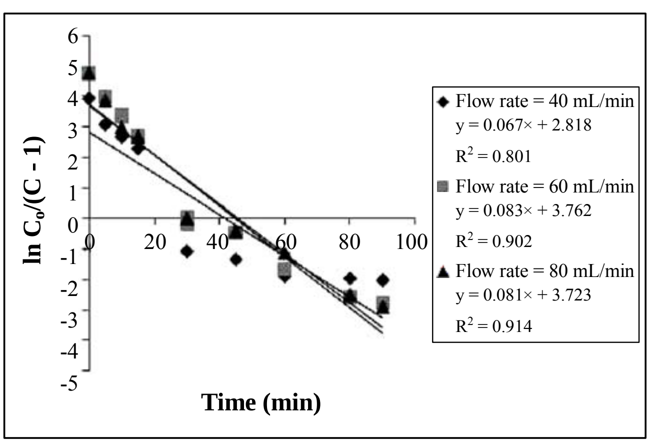

Fig. 6: Effect of flow rate on Thomas-BDST model

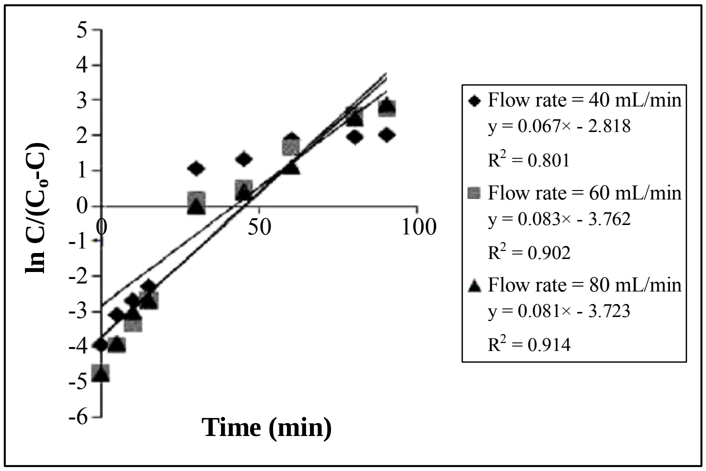

Fig. 7: Effect of flow rate on Yoon Nelson model

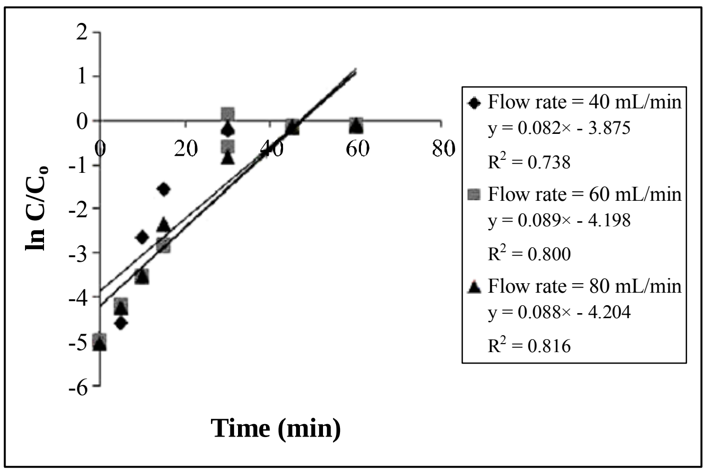

Fig. 8 Effect of flow rate on Adams-Bohart model

Effect of bed height

As shown in Fig. 9, with increase in the bed height, the break through and saturation time delays. For bed heights of 40, 50 and 60 cm for initial concentration of 1000 mg/L, the time required for breakthrough was 80, 90 and 100 min, respectively. It was observed that q_0 decreased with bed height, Yoon Nelson time constant decreased with bed height. In case Adam Bohart model, N_0 decreased with bed height. Effect of bed height on model parameters is shown in Fig. 10 to 12.

Table 7: Effect of bed height for thomas model

Parameters	Flow rate (cm) at fixed bed height, initial concentration and pH		
	40	**50**	**60**
K_T (mL/min/mg)	0.085	0.092	0.098
q_0 (mg/g)	23.435	22.22	21.56
$_R2$	0.902	0.903	0.901

Table 8: Effect of bed height for yoon nelson model

Parameters	Bed height at fixed initial concentration, flow rate and pH (cm)		
	40	50	60
k (/min^{-1})	0.098	0.092	0.085
(min)	46	44.44	39
$_R2$	0.92	0.903	0.899

Table 9: Effect of bed height for adams-bohart model

Parameters	Bed height at fixed initial concentration, flow rate and pH (cm)		
	40	**60**	**80**
K_{AB} (mL/min/mg)	0.077	0.083	0.078
N_0 (mg/L)	3788.9	3065	2648
$_R2$	0.88	0.881	0.883

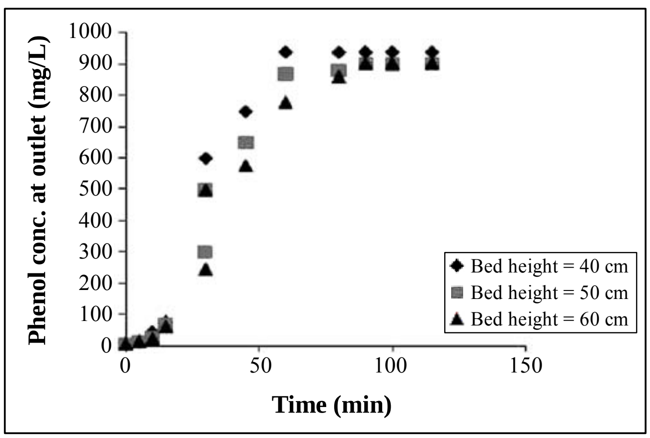

Fig. 9 Effect bed height on breakthrough curve

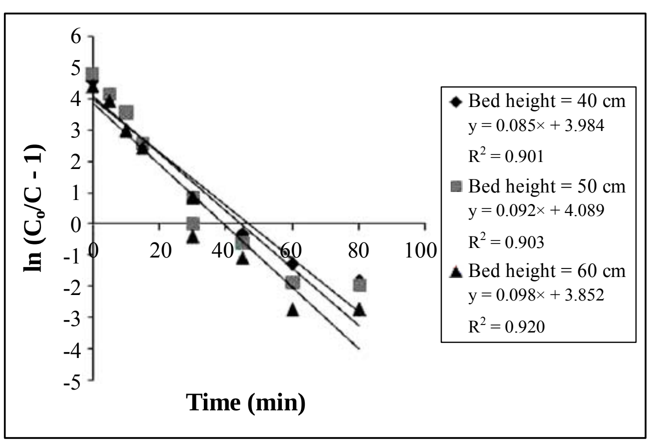

Fig. 10: Effect of bed height on Thomas-BDST model

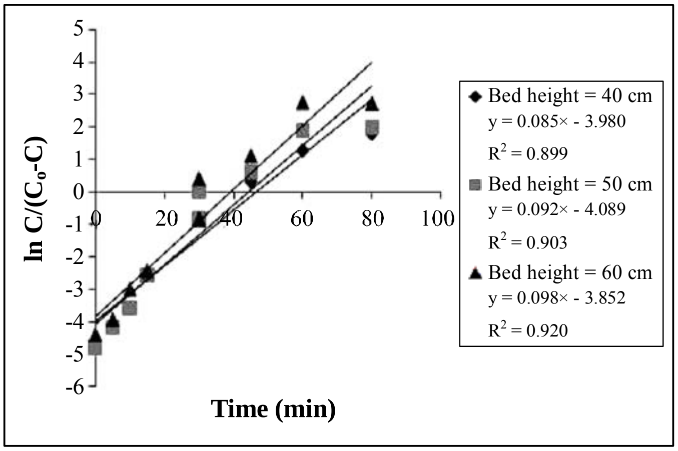

Fig. 11: Effect of bed height on Yoon Nelson model

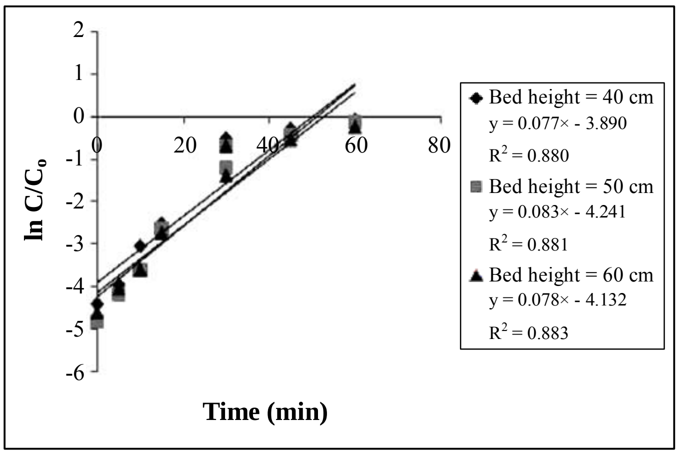

Fig. 12: Effect of bed height on Adams-Bohart model

CONCLUSION

Packed column studies suggested that rice husk adsorption in packed column is very efficient method with C/C_0 values of 0.9 to 0.95. Almost 95 percent removal was possible in the column. For the most of the experiment data, Thomas model provided best fit followed by Yoon Nelson model. Adam Bohart model indicated moderate fit to the experimental data with R^2 value ranging from 77 to 90 percent. For optimum flow rate of 60 mL/min and initial concentration of 1000 mg/L, Adam Bohart model was able to describe the break through curve better fit. Experimental average time required for 50 percentage saturation was 30 to 35 min while Yoon Nelson time constant was in the range of 35 to 42 min. So the theoretical values were in reasonable agreement with experimental values.

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