Groundnut Shell Adsorbent in Packed Bed for Cadmium Removal- Modeling for Breakthrough Curve

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Abstract

Cadmium removal from effluent can be carried out by using various low cost adsorbents prepared from waste materials. The continuous removal of cadmium can be carried out in packed bed. In the current investigation groundnut shell derived adsorbent is used for removal of cadmium from synthetic effluent in a packed bed. The effect of various parameters like initial concentration, flow rate and bed height on the break through curve is studied. It was observed that the exhaustion time decreases with increase in initial concentration and flow rate and it increases with bed height. Experimental data was fitted in three models namely Thomas- BDST, Yoon Nelson and Adam Bohart. Thomas model was most satisfactory for the packed bed cadmium removal by groundnut shell. The values of the model parameters were evaluated and analyzed.

Keywords- *break through curve, model parameters, flow rate and solute uptake.*

I. INTRODUCTION

Adsorption is one of the most widely used methods for removal of pollutants from wastewater. It can be used effectively for removal of organic matter from the wastewater [1,2,3]. Adsorption can be used as an effective technique for removal of heavy metals from wastewater. Batch and column studies for heavy metal are reported by investigators with removal efficiencies above 90 percent[4,5,6]. Batch studies for heavy metals include optimization of various parameters such as initial concentration, adsorbent dose and pH. Also studies indicated that Langmuir and Freundlich isotherms are obeyed by solute uptake in most of the cases. The kinetic studies for heavy metal removal by adsorption are also reported[7,8,9]. The practical application of the adsorption calls for continuous operation. Fixed bed and fluidized bed contactors can be used efficiently for heavy metal removal[10,11,12]. Cadmium is one such heavy metal which is added to water and soil through the effluent from battery, catalyst, paint, mining and many other industries. It affects human being adversely when injected into human bodies. It can cause both long term and short term diseases in human beings and other aquatic life[13,14,15]. The cadmium removal by adsorption is very effective way of treatment. Batch and column studies for cadmium removal by using low cost adsorbents such as fly ash, leaf litter, groundnut shell, coconut shell, cashew shells, peanut shells etc. has been reported with satisfactory results[16,17,18]. The present investigation aims at studying the effect of parameters like initial concentration, flow rate and bed height on break through curve and using different models to describe the break through curves. The models used in this study are Thomas model, Yoon Nelson model and Adam Bohart model.

II. MODELS FOR BREAKTHROUGH CURVE

A. *Thomas – BDST Model*

Thomas – BDST Model based on Langmuir kinetics is expressed as follows[19,20]].

$$\frac{C}{C_0} = \frac{1}{1+\exp[\frac{K_T}{Q}(q\,M - C_0\,V)]} \quad (1)$$

$$\ln\left(\frac{C}{C_0} - 1\right) = \frac{K_T\, q_0\, M}{Q} - C_0\,\frac{K_T\, C_0}{Q}\, V \quad (2)$$

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).

B. *Yoon Nelson model*

It is expressed as following equation[19,20].

$$\frac{C}{C_0} = \frac{1}{1+\exp(K(\tau - t))} \quad (3)$$

$$\ln\frac{C}{C_{0-C}} = k\,t - \tau\, k \quad (4)$$

Here, k is the rate constant, τ is time required for 50 percent adsorbate break through and t is sampling time.

C. The Adams-Bohart Model

The Adams-Bohart model is represented by following equation[19,20].

$$\frac{C}{C0} = \exp(k_{AB}\ C_0\ t - k_{AB}\ N_0\ \frac{Z}{u0}) \quad (5)$$

$$\ln\frac{C}{C0} = k_{AB}\ C_0\ t - k_{AB}\ N_0\ \frac{Z}{u0} \quad (6)$$

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.

III. METHODOLOGY

Groundnut shells were obtained from the farmers from Salgar Budruk in Solapur district in Maharashtra, India. These shells were first sundried and then washed with distilled water. Then they were heated to 150 ^oC for 4 hours. Also treatment with zinc chloride was carried out. Then these shells were washed with dilute sodium hydroxide and dilute sulphuric acid. Again they were washed with water and activated at 350-400 ^OC. Three columns used were 5 cm in diameter and 100 cm in height. The effluent was allowed to flow through gravity. The samples were analyzed by using U.V. specrophotometer using alizarin red as an indicator.

IV. ANALYSIS OF ADSORBENT

Quanta 200 ESEM (Scanning Electron Microscope) system was used for testing adsorbent. Fig.1(a,b,c,d) shows SEM diagram for the groundnut shell adsorbent for studying structure of groundnut shell adsorbent at different spots. The size of particles ranged from 10 to 100 µ m. EDX diagram (Energy Dispersed X-ray) is shown in fig.2. The analysis of adsorbent indicated that carbon was a major components with 62 to 68 percent by weight.

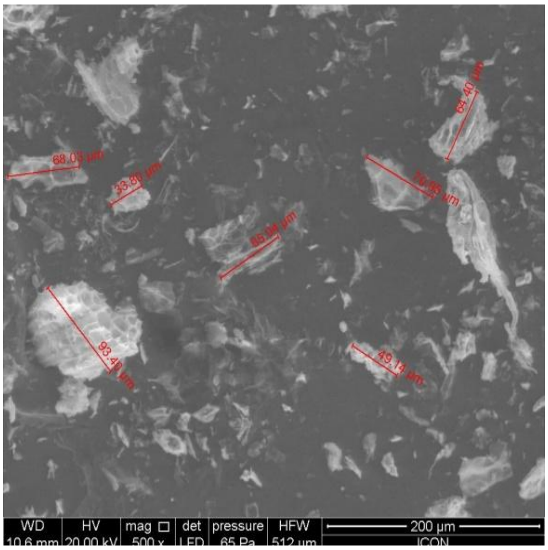

FIG.1.a: SEM Analysis

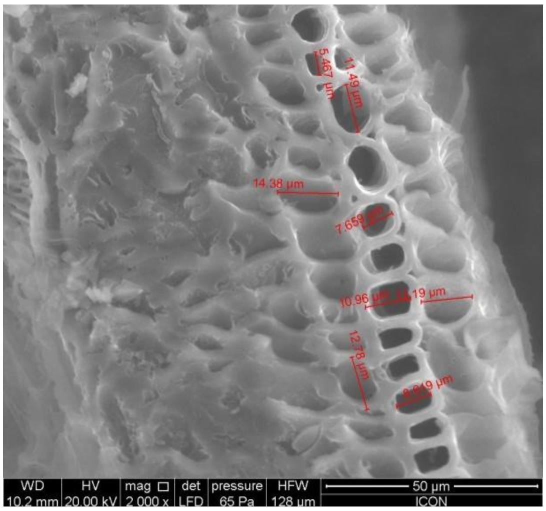

FIG.1.b: SEM Analysis

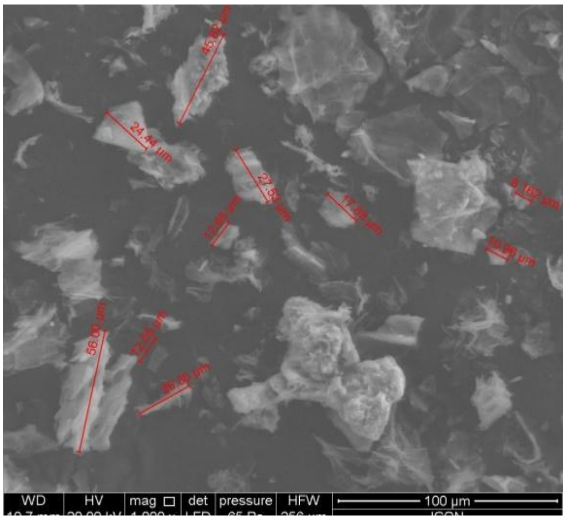

FIG.1.c: SEM Analysis

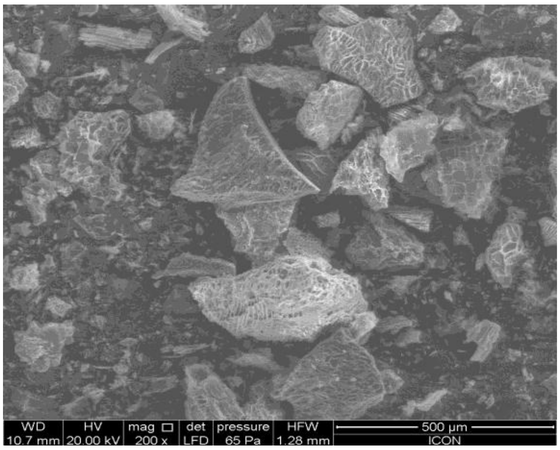

FIG.1 d: SEM Analysis

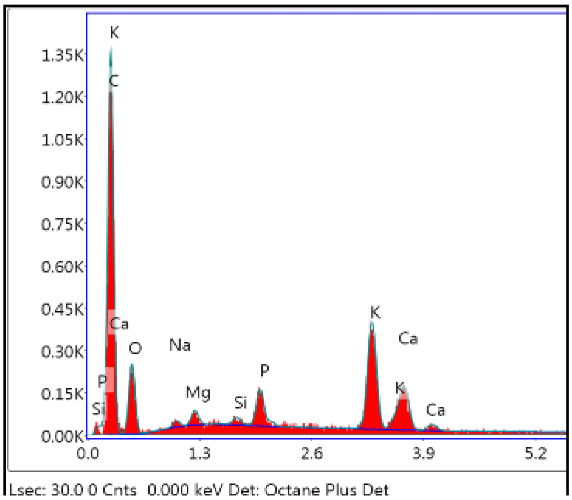

FIG.2 a: EDX diagram for adsorbent

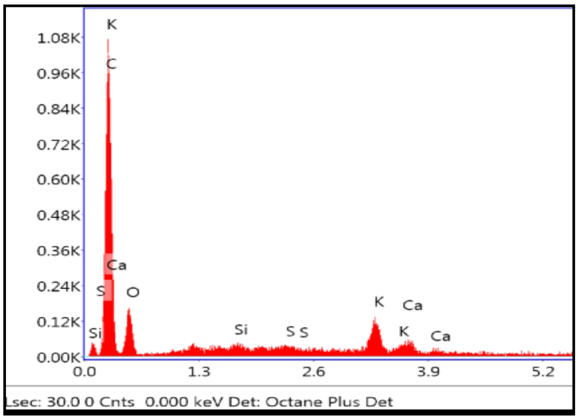

FIG.2 b: EDX diagram for adsorbent

V. RESULTS AND DISCUSSION

A. Effect of Initial Concentration

Effect of initial concentration on cadmium removal is shown in fig.3. With increase in initial concentration from 10 mg/l to 50 mg/l, the break through time decreased. The time required for exhaustion decreased from 65 minutes to 45 minutes for increase in concentration form 10 mg/l to 50 mg/l. Fig. 4 to 6 shows effect of initial concentration on Thomas, Yoon Nelson and Adam Bohart model respectively. First two models were satisfactory for break through curves. The adsorption capacity estimated by Thomas model increased from 0.21 to 1.06 for increase in concentration form 10 to 50 mg/l. Yoon Nelson constant k decreased with concentration. τ decreased with increase in concentration. Adam Bohart model parameter N_0 increased with concentration. K_{AB} decreased with concentration.

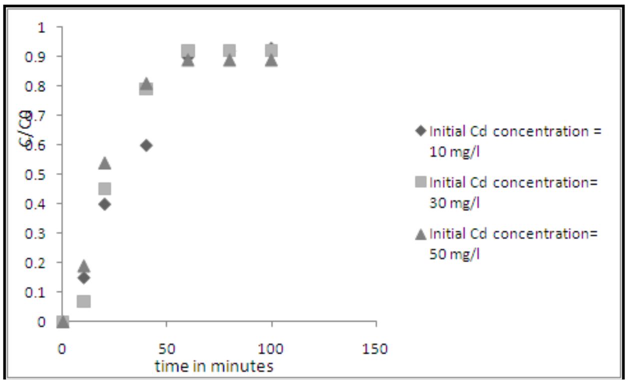

FIG.3: Effect of C_0

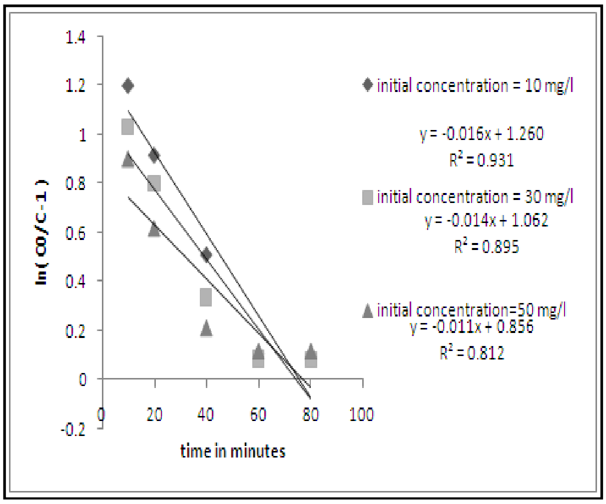

FIG.4: Thomas Model at Different C_0

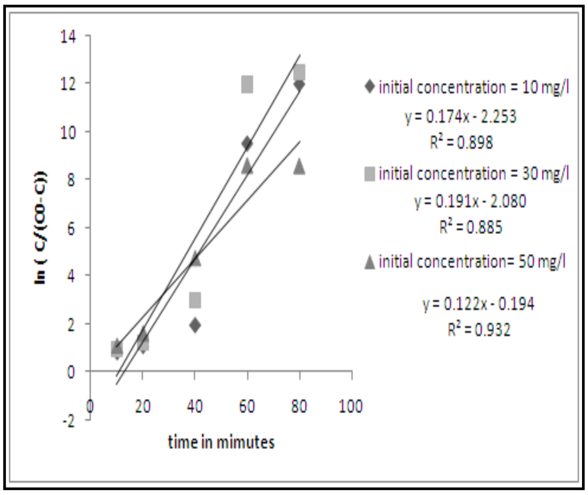

FIG.5: Yoon Nelson Model at different C_0

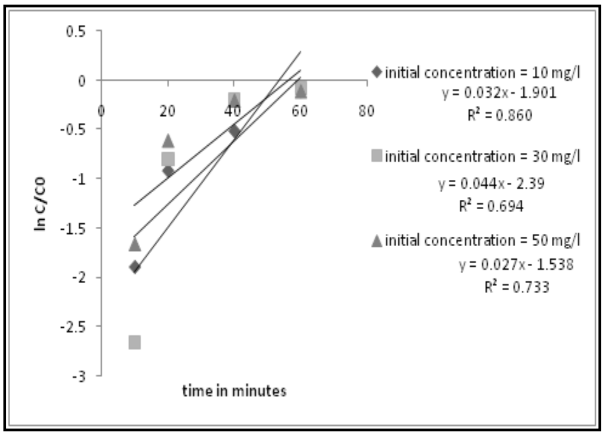

FIG.6: Adam Bohart Model at different initialC_0

B. Effect of Flow Rate

Fig. 7 shows effect of flow rate on breakthrough curve. Thomas model and Yoon Nelson models were able to explain the break through curve. Adam Bohart model was not much satisfactory with R^2 values from 0.7 to 0.8. K_T, Thomas constant decreased with flow rate while q_0 increased with flow rate. Exhaustion time decreased from 100 minutes for 16 ml/min to 60 minutes for 50 ml /min. Fig. 8 to 10 shows the Thomas, Yoon Nelson and Adam Bohart model diagrams for different flow rates. K_{AB} in Adam Bohart equation decreased with flow rate. There was sharp rise in N_0 with increase in flow rate.

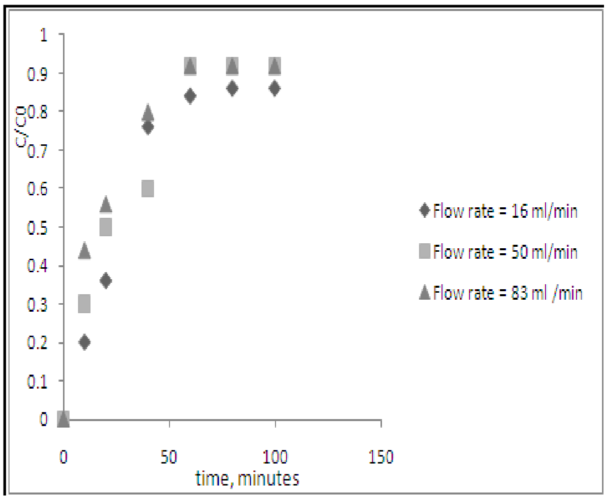

FIG.7: Effect of Flow Rates

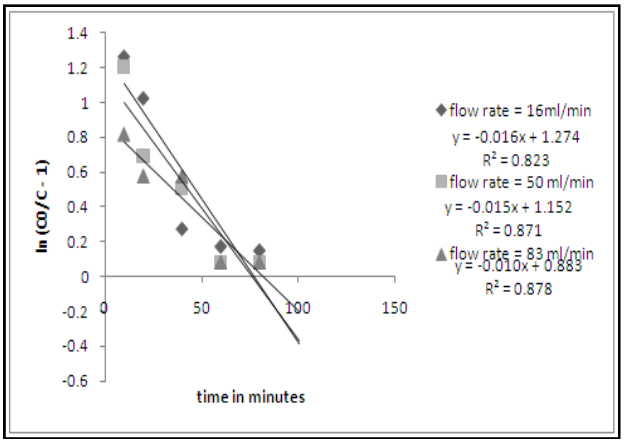

FIG.8:Thomas model at different flow rates

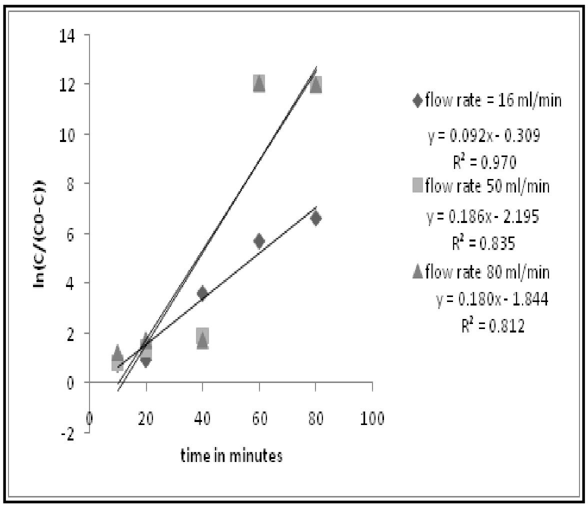

FIG.9:Yoon Nelson Model at different flow rates

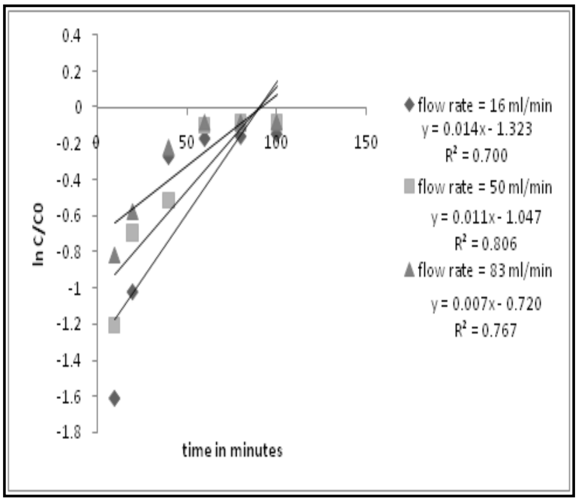

FIG.10:Adam Bohart Model at Different Flow Rates

C. Effect of Bed Height

Effect of bed height on C/C0 was studied for three bed heights.. Fig. 11 shows effect of bed height on breakthrough curve. Thomas model and Yoon Nelson models were able to explain the break through curve. Adam Bohart model was not much satisfactory with R^2 values from 0.67 to 0.8. K_T, Thomas constant increased with bed height while q_0 decreased with bed height.. Fig. 12 to 14 shows the Thomas, Yoon Nelson and Adam Bohart model diagrams for different flow rates. τ, time required for 50 percent break through increased with bed height. N_0 in the Adam Bohart equation decreased with bed height.

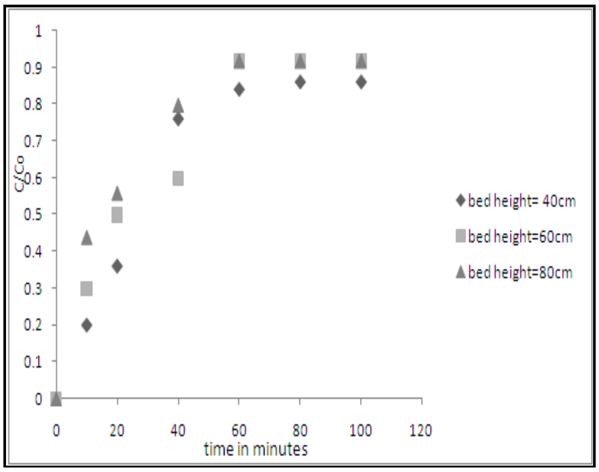

FIG.11: Effect Bed Heights

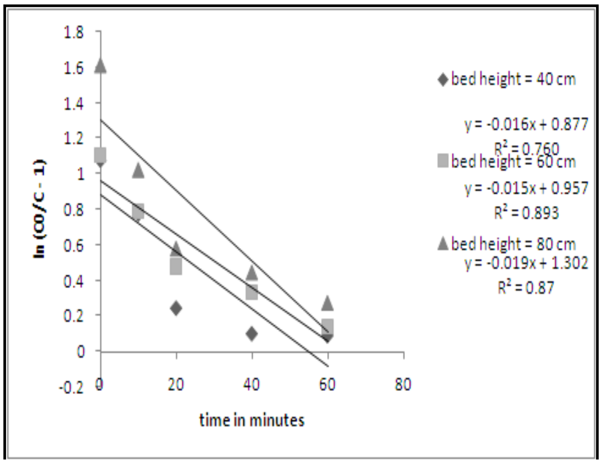

FIG.12:Thomas Model at Different Bed Heights

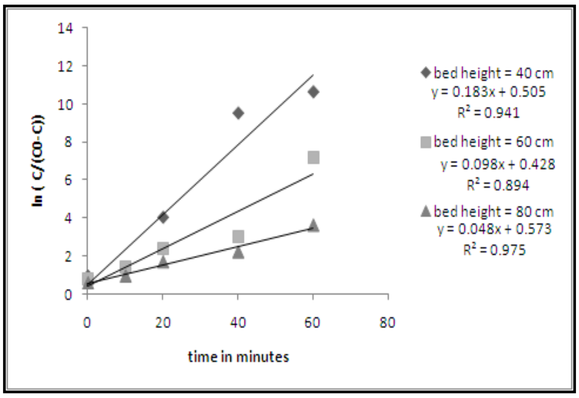

FIG.13:Yoon Nelson Model at Different Bed Heights

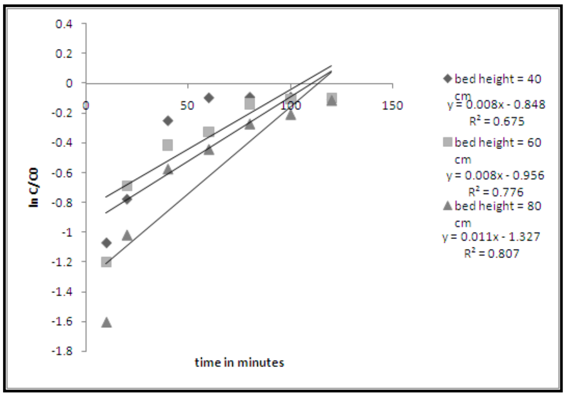

FIG.14: Adam Bohart Model at Different Bed Heights

VI. CONCLUSION

Packed bed adsorption is effective method for application of adsorption for removal of heavy metals like cadmium. Low cost adsorbent prepared from groundnut shells was efficient in removing the cadmium from synthetic effluent. Breakthrough time and exhaustion time decreased with increase in initial concentration and flow rate. With increase in bed height, the break through time and exhaustion time delays. Thomas model was found to be most suitable for the break through curve followed by Yoon Nelson model and Adam Bohart model.

TABLE 1: model parameters

Thomas Model Parameters									
Parameters	Initial Concentration (mg/l)			Bed Height(cm)			Flow rate(ml/min)		
	10	30	50	40	60	80	16	50	83
K_t ml/min/mg)	1.6	0.46	0.22	0.3	0.3	0.38	0.32	0.3	0.2
q_0 (mg/g)	0.216	0.63	1.06	1.123	.86	0.71	0.359	0.92	2
R^2	0.931	0.895	0.912	0.893	0.87	0.793	0.823	0.871	0.878
Yoon Nelson Model Parameters									
k(min $^{-1}$)	0.174	0.141	0.122	0.183	0.098	0.048	0.092	0.186	0.18
T(min)	12.94	10.89	1.6	2.759	4.6	11.93	3.46	11.8	10.3
R^2	0.89	0.88	0.93	0.94	0.89	0.97	0.97	0.835	0.812
Adam Bohart Model Parameters									
K_{AB}(ml/min/mg)	0.0032	0.00146	0.00054	0.00016	0.00016	0.00022	0.0002	0.00022	0.000016
N_0(mg/l)	25.24	69.57	121.04	337	253.9	192.6	64.26	202.27	3175
R^2	0.86	0.69	0.73	0.67	0.77	0.80	0.7	0.8	0.76

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