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Adsorption of Phenol on Xanthoceras Sorbifolia Bunge Hull Activated Carbon

Yinan Hao, Ximing Wang and Xiaotao Zhang

ABSTRACT

Adsorption of phenol from aqueous solution onto Xanthoceras Sorbifolia Bunge hull activated carbon (XSBHAC) developed by phosphoric acid activation has been investigated. Experiments were carried out as function of initial concentration, time, pH value and temperature. The results showed that maximum adsorption capacity of zinc (II) reached 200.031 mg/g at an initial phenol concentration, solution pH value, adsorption temperature, and adsorption time of 300 mg/L,3.67, 25ºC and 60min, respectively. Adsorption isotherms were modeled with the Langmuir and Freundlich isotherms. The data fitted well with the Freundlich isotherm. The rates of adsorption were found to conform to the pseudo-second-order kinetics with good correlation. It could indicated that the ado sorption system belonged to polymolecular layer was an exothermic process. It was concluded that increased temperature was disadvantage for phenol adsorption onto XSBHAC. The results in this study indicated that XSBSHAC was a good adsorbent for removing phenol.

INTRODUCTION:

Phenol is a well-known toxic substance and can threaten human life through the food chain via bioaccumulation. China health organization recommended the maximum acceptable concentration of phenol in drinking water is 0.002mg/L. Removal of phenol or decreasing its concentration to the permitted levels before

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discharge is necessary so as to prevent deleterious effects on the ecosystem and public health. Lots of methods have been employed to remove phenol from wastewater, such as chemical precipitation method[1], ion exchange method[2]and adsorption method[3]. One of the effective methods of treating phenol from aqueous solution is the production of activated carbon. The activated carbon has been produced from variety of biomass such as cocoa shell[4], soybean hull[5] and coconut shell.

The production of activated carbon from forestry product-Xanthoceras Sorbifolia Bunge hull, which is mainly distributed in Inner Mongolia in China. The aim of this study was to evaluate the potentiality of XSBHAC for the removal of phenol from aqueous solution.

EXPERIMENTAL

Materials

Xanthoceras Sorbifolia Bunge's hulls(XSBH) which developed by phosphoric acid solution (85wt%) activation and was mixed at 500 °C for 12 h was used in the present investigation was obtained from Chifeng, China. Phenol was obtained from Tianjin Chemical Co., China, with analytical grade that was used without further purification.

Methods

The adsorption experiments was carried out on a thermostatic shaker (SHA-C, China) operated at 150rpm, 0.05g adsorbent and 50mL phenol solution (initial concentration 300mg/L)were used. The system was maintained 60min under shaking at 25°C until adsorption equilibrium was reached. The adsorption capacity of phenol solution was calculated by the following equation :

$$Q = \frac{(Co - Ce) \times V}{m} \tag{1}$$

where Q (mg/g) refers to the capacity of adsorption at time t (min). Co and Ce (mg/L) refer to the phenol initial concentration and final concentration at time t (min).

RESULTS AND DISCUSSION

Effect of pH Value on Adsorption

As seen from Fig.1, it was evident that increasing the pH of solution serves to increase the adsorption capacity in the adsorption process occurring as the pH increased from 2.64 to 3.67. The maximum adsorption capacity toward phenol was attained at a pH value of 3.67. The result can be explained on the competition between H+ and phenol for activated adsorption sites on XSBHAC surface at low pH levels, when pH increased, the covered H+ leave the activated carbon surface and made more available adsorption sites for phenol. When pH value above 3.67, phenol existed in the forms of anion[6], as increased in pH value, the adsorption capacity of phenol was decreased.

Effect of Temperature on Adsorption

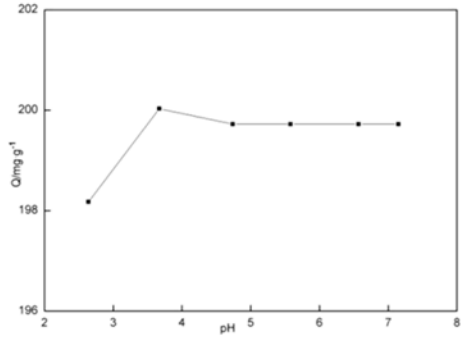

Figure 1. The effect of initial pH on adsorption.

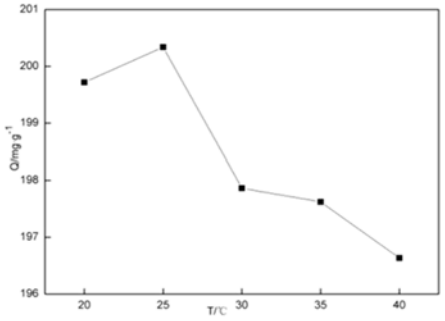

Figure 2. The effect of temperature on adsorption.

The effect of temperature on the adsorption rate of phenol on activated carbon was investigated at 293, 298,303,.308 and 313K in Fig.2.As can be seen, the adsorption capacity of XSBHAC increased as the temperature was increased from 25 to 30 ºC, indicating that high temperatures facilitated the adsorption of phenol on the surface of XSBHAC. The result can be attributed to the fact that high temperature may produce a loosen effect within the structure and activate the functional groups of XSBHAC, adsorbing phenol into the structure of activated carbon further. The adsorption capacity decreased when the temperature above 25ºC, thereby indicating the exothermic behavior of the adsorption process. So, high levels of phenol ion activity led to the desorption energy was greater than the adsorption energy[7] .

Effect of Time on Adsorption

As seen from Fig.3, with the beginning of adsorption the adsorption capacity increased quickly, then 60min later, the adsorption capacity decreased. It was reported that during adsorption of phenol, initially the phenol molecules reach the boundary layer; then they have to diffuse into the adsorbent surface. And finally, they have to diffuse into the porous structure of the adsorbent. Therefore, it can be suggested that the optimal time value for adsorption phenol was 60min in this study.

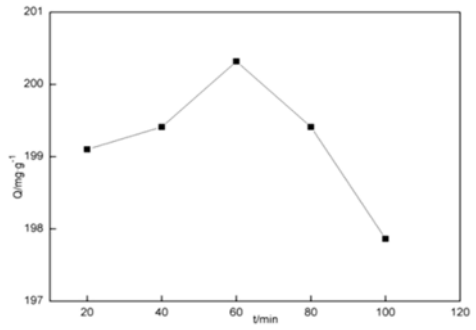

Figure 3. The effect of time on adsorption.

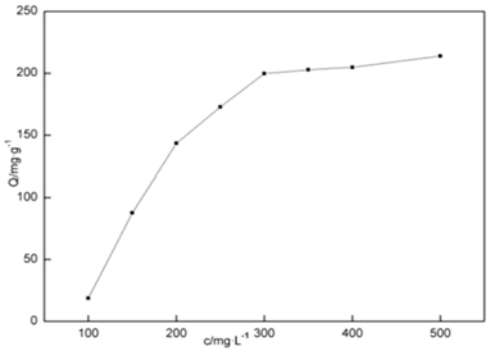

Figure 4. The effect of initial concentration on adsorption.

Effect of Initial Concentration on Adsorption

As seen from Fig.4, the adsorption capacity of XSBHAC increased as initial concentration was increased from 100 to 300mg/L. then the change became slow. The adsorption force for surface of liquid phase and solid phase increased, because the phenol initial concentration increased, Initially activated carbon particles had enough active adsorption, the adsorption capacity of phenol increased. If the concentration of phenol further increased, although the equilibrated adsorption capacity increased, residual liquid after adsorption of phenol remaining concentration was too high[8], activated carbon loci reached saturation, therefore, the adsorption capacity was no longer increased.

Adsorption Kinetics

The pseudo-first-order $$\log(Qe - Qt) = \log Qe - (\frac{K_1}{2.303})t \quad (2)$$

The pseudo- second-order $$\frac{t}{Qt} = \frac{1}{K_2 Qe^2} + (\frac{1}{Qe})t \quad (3)$$

Where Qe and Qt (mg/g) are the amounts of phenol adsorbed at equilibrium and at time t (min), and k1 (1/min), k2 (g/(mg·min))are the rate constant of adsorption.

The kinetic models for phenol adsorption onto the activated carbons were shown in Figs.5 and 6, the results of kinetic parameters were shown in Table1. It can be seen that the calculated Qe was not in good agreement with the experimental data and the value of R2 (0.2828) was not satisfactory. Therefore, the pseudo-first-order model was not suitable for modeling the adsorption of XSBHAC. The pseudo-second-order model fitted well with the value of R2 (0.9999). In the Table 1, it was clearly seen that the calculated Qe values (196.0784mg/g) agreed with the experimental data (200.3190mg/g), indicating that the pseudo-second-order kinetics model would be successfully by the adsorption process of XSBHAC.

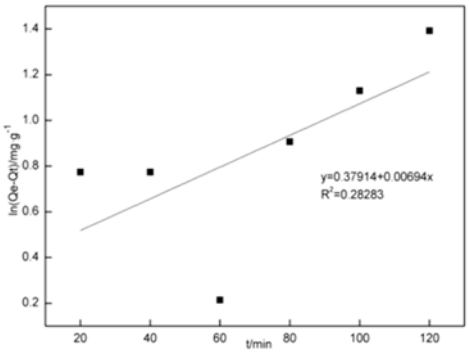

Figure 5. Pseudo-first-order kinetics for adsorption.

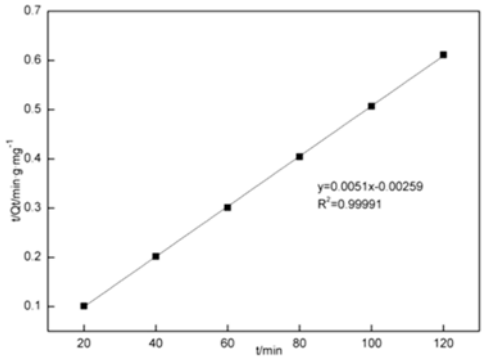

Figure 6. Pseudo-second-order kinetics for adsorption.

TABLE I. KINETIC PARAMETERS FOR ADSORPTION.

Qe（exp）	Pseudo-first-order			Pseudo-second-order		
T/K / mg·g^{-1}	R^2	Qe/mg·g^{-1}	K_1/min^{-1}	R^2	Qe/mg·g^{-1}	K_2/g·(mg·min)$^{-1}$
298 200.3190	0.2828	123.7349	0.006	0.9999	196.0784	0.01004

Adsorption isotherms

Langmuir $$\frac{Ce}{Qe}=\frac{1}{K_L\times Qm}+\frac{Ce}{Qm} \quad (4)$$

Freundlich $$Q=K_F\times C^{\frac{1}{n}} \quad (5)$$

Where Qm (mg/g) and KL (L/mg) are Langmuir isotherm coefficients. The value of Qm represents the maximum adsorption capacity. KF(L/g) and n are Freundlich constants.

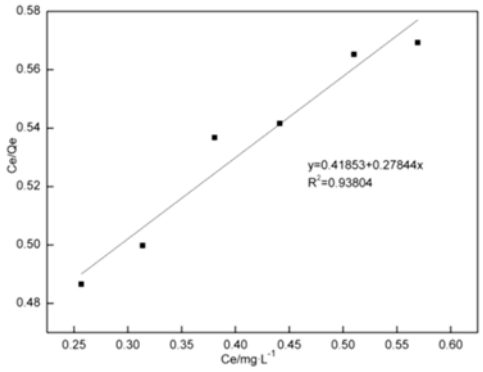

Figure 7. Adsorption isothermal curve of Langmuir.

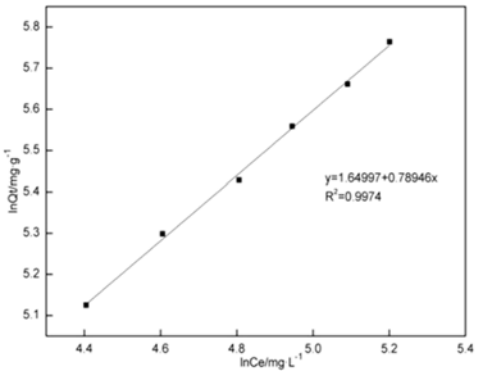

Figure 8. Adsorption isothermal curve of Freundlich.

The linear plot of Langmuir and Freundlich models of the adsorption of phenol (Fig.7 and 8).As it is seen from Table.2 the Freundlich isotherm model which belonged to polymolecular layer adsorption yielded the best fit with the highest R2 value (0.9974) at 25ºC compared to the Langmuir model. It is generally recognized that the value of 1/n described the nature of the adsorption either: （0.1＜1/n＜0.5)easy adsorption;（1/n＞2）hard adsorption[9]. In this study, the 1/n value were calculated (0.2602) and shown in Table 2, which confirmed that XSBHAC were favorable for phenol adsorption under the adsorption condition employed.

TABLE II. REGRESSION PARAMETERS FOR LANGMUIR AND FREUNDLICH ISOTHERMS.

T(K)	Langmuir equation			Freundlich equation		
	R^2	K_L/L·mg^{-1}	R_L	K_F	R^2	1/n
298	0.93804	0.07752	0.02706	53.4694	0.9974	0.2602

CONCLUSION

The adsorption of phenol using XSBHAC as adsorbent has been investigated under different experimental conditions. The results indicated that, adsorption capacity of the adsorbent considerably affected by preparation of initial concentration, pH, time and temperature. The adsorption equilibrium was best defined by the Freundlich isotherm model which belonged to the polymolecular layer adsorption at 25 ºC compared to the Langmuir model; The pseudo-second

order equation provided the better correlation of the adsorption data; It was concluded that increased temperature was disadvantage for phenol adsorption onto XSBHAC. The adsorption was an exothermic process. Overall, XSBHAC produced in this study exhibited the potential for application as an alternative low-cost adsorbent in the removal of phenol.

ACKNOWLEDGEMENT

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