FIXED BED ADSORPTIVE REMOVAL OF Pb (II) IONS FROM AQUEOUS SOLUTION USING ACTIVATED CARBONS

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Introduction

Lead treatment and recovery plants, paint and ceramic industries discharges lead as an effluent on the surface which then find its way to surface water. It forms complexes in human body and interfere with several body processes. Lakshmi and Srinivasan [1], Kanan and Raj [2] observed that the Pb uptake increased with increase in agitation time, dose and initial pH. Some other workers investigated the equilibrium adsorption [3, 4] of pb(II)ions and found that it depends on the pH of the solution and the surface acidity of the carbon surface. The dynamic studies [5, 6, 7] were carried under varying conditions of pH, the bed depth and concentration of Pb(II) ions in the solution.

Expeimental

The fixed bed adsorption studies of Pb(II) ions from aqueous solution have been carried out on two activated carbons namely a granulated activated carbon (GAC) and a sample of activated carbon cloth (ACC). Pb (II) ions solution of known concentration was prepared and poured into overhead tank. A control valve to regulate the flow and a rotameter to monitor the flow rate are installed in the system. The details of the experimental set up are published elsewhere [8]. The effluent from the column is collected at regular intervals and analyzed by titration against 0.01 EDTA solution at pH = 6 using hexamine as buffer and xylenol orange as indicator [9]. The operating variables in these investigations are the hydraulic loading rate (HLR, 0.61-1.22 $m^3/hr/m^2$) which is the volume flow rate per unit cross sectional area of the adsorbent bed, the bed depth (50-150mm) and the feed concentration, C_o (50 - 150mg/L).

Results and Discussions

The breakthrough curves for Pb (II) ions showing effluent concentration as a function of time for the two activated carbons with HLR $1.22 m^3/hr/m^2$, carbon bed depth of 100mm and a feed concentration of 50mg/L are presented in Fig.1. It is seen that the period of slow rise in effluent concentration and the breakthrough time t_b are longer for the carbon cloth than for the granulated carbon.. The breakthrough curves at different bed depths HLR and feed concentrations show that the breakthrough time increases on increasing the bed depth but decreases on increasing the feed concentration and HLR. This indicates that ACC is a better adsorbent for Pb (II) ions. The amount of Pb (II) ions adsorbed by a carbon at different HLR has been calculated from the breakthrough time t_b at 50% breakthrough concentration C_b using the following relationship

$$\text{Adsorption capacity} = \frac{t_b . Q . (C_o - C_b)}{m} \quad \text{---- (1)}$$

where Q is the liquid flow rate in litres per hr, C_o is the feed concentration, C_b is the effluent concentration in mg/L and m is the mass of the carbon in the bed (g). The maximum adsorption capacity for granulated activated carbon is 2.85mg/g corresponding to HLR of $1.22m^3/hr/m^2$ and is around 17.66mg/g for the carbon cloth.

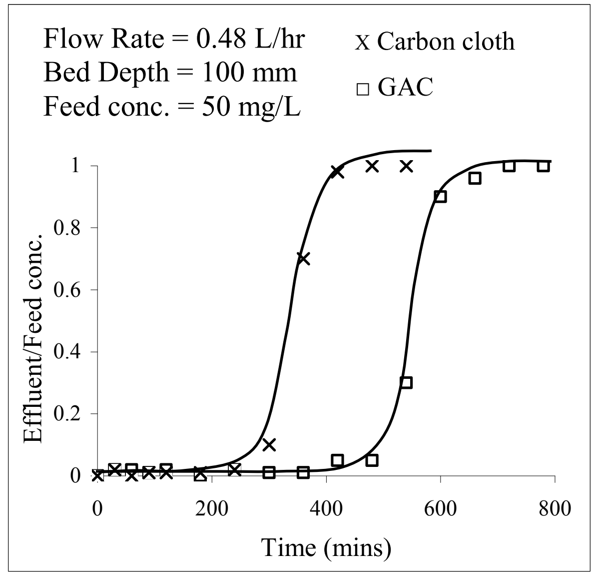

Fig.1 Breakthrough curves of Pb(II) ions on both carbons

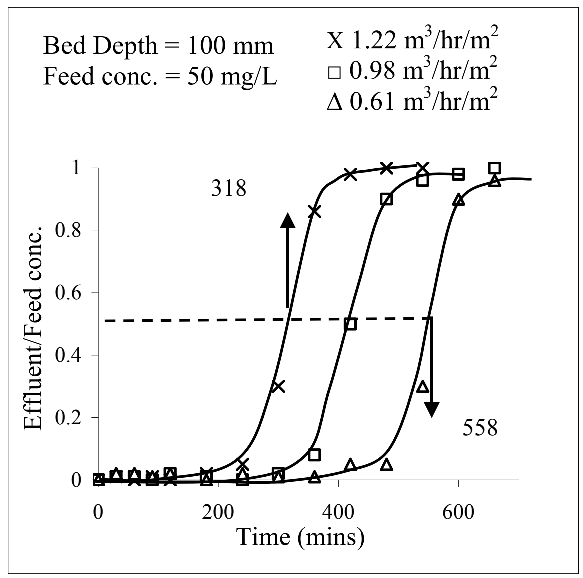

Fig.2 Effect of HLR on breakthrough curve for ACC

Adsorption zone parameters

Michaels [10] suggested a mathematical treatment to calculate the adsorption zone parameters. The values of adsorption zone parameters such as the height of the exchange zone (h_z), the rate of movement of the adsorption zone down the bed (U_z), time required for the adsorption zone to move to its own height down the column t_z for 5, 10 and 15 cm bed heights are given in Table 1.

Bohart-Adam Model

The Bohart-Adam equation [11] which is based on the surface rate reaction theory and defines a relationship between the bed depth *x* and the breakthrough time t_b for a given concentration of the effluent can be expressed as

$$t = \frac{N_o}{C_o V} x - \frac{1}{C_0 k} \ln\left(\frac{C_o}{C_b} - 1\right) \quad \ldots\ldots\ldots\ldots\ldots.. (2)$$

At t = 0 the equation can be solved for x as

$$x_o = \frac{V}{kN_o} \ln\left(\frac{C_o}{C_b} - 1\right) \quad \ldots\ldots\ldots\ldots\ldots.. (3)$$

where C_o is the concentration of solute in the feed solution (mg/L), C_b is the desired effluent concentration (mg/L), x is the bed depth (cm), x_o also called critical bed depth is the minimum bed depth (cm) of the adsorbent sufficient to produce an effluent concentration C_b , k is the adsorption rate constant (L $mg^{-1}hr^{-1}$), N_o is the adsorption capacity (mg/cm^3),V is the linear flow velocity ($L/hr/cm^2$) and t is the service time of the column under these conditions (hr). The values of x_o calculated from theoretical and experimental considerations agreed closely (cf table 1).

Table 1. Parameters using BDST plots for feed conc. of 50 mg/L

Carbon Sample	Flow Rate L/hr	Critical bed depth,cm	
		using eq. (3)	From Fig.3
Carbon cloth	0.3	2.0	2.1
	0.48	2.17	2.2
	0.60	2.3	2.4

Yoon Nelson and Wolborska Model

The values of 50% breakthrough time (τ) were calculated using Yoon-Nelson model equation [12]

$$\ln\left(\frac{C_b}{C_o - C_b}\right) = K_{YN} t - \tau K_{YN} \ldots\ldots\ldots\ldots \quad (4)$$

where k_{YN} is the Yoon-Nelson rate constant (min^{-1}), τ is the 50% breakthrough time (min) and the values of adsorption capacity were calculated using Wolborska model [13]

$$\ln\left(\frac{C_b}{C_o}\right) = \beta \frac{C_o}{N_o} t - \beta \frac{Z}{U} \quad \text{-------------------} (5)$$

where β is the kinetic coefficient of external mass transfer (min^{-1}), and the other symbols have the same significance as before. The experimental values and Yoon-Nelson values of τ and the values of adsorption capcity N_o from BDST and Wolborska model agreed closely (cf Table 2).

Table 2.Parameters predicted from Yoon Nelson model and Wolborska model for ACC

Flow Rate (ml/min)	Yoon-Nelson breakthrough time		Adsorption capacity(mg/cm^3)	
	$\tau_{cal.}$ (min)	$\tau_{exp.}$ (min)	Wolborska model	BDST model
5	476	588	3.5	3.0
8	366	396	4.6	3.6
10	290	318	4.4	2.9

Conclusion

The breakthrough time of Pb (II) ions on GAC and ACC increases with increase in the bed depth but decreases on increasing the hydraulic loading rate and the feed concentration. The adsorption capacity of the carbon bed increases with the HLR and is maximum at HLR of 1.22 $m^3/hr/m^2$. The critical bed depth and the depth of mass transfer zone obtained using the BDST theoretical approach agree closely with the experimental values. The breakthrough time at 50% effluent concentration agreed with the values obtained using Yoon Nelson equation and adsorption capacity obtained using BDST and Wolborska equations agreed with each other.

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