Pb (II) Ions Adsorption onto Biomaterial Chitosan Hydrogel Beads - Isotherm And Kinetic Studies

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Abstract

The present research work attempted to investigate the batch mitigation of Pb (II) ions from water onto chitosan hydrogel beads (CHB) as an adsorbent. The batch adsorption of Pb (II) ions onto CHB was studied as a function of various parameters viz. pH, contact time, initial Pb (II) ions concentration and adsorbent doses. The equilibrium adsorption data were fitted by the Langmuir and Freundlich models where the maximum uptake of Pb (II) ions obtained as 8.928 mg/g. The adsorption kinetics was evaluated by pseudo first order and Pseudo second order kinetics mechanism. The adsorption data well obeyed pseudo second order kinetics.

Keywords: Chitosan; Pb (II) ions; Adsorption; Isotherm; Kinetics.

Introduction

Pb (II) ions pollution in water or industrial wastewater is of distinctive concern for the environmentalist and medical health scientist due to its extreme toxicity even in smaller amount and having no any biological role [1]. It affects nearly every physiological organ system viz. liver, kidneys, reproductive system, gastrointestinal system etc. [2]. Several treatment technologies for Pb (II) ions mitigation from water viz. chemical precipitation, membrane separation, ion exchange, coagulation, reverse osmosis, evaporation and adsorption are developed [3]. Amongst all these techniques, adsorption process is comparatively found to be effective and economic for water treatment application [4]. Nevertheless the main pitfall of adsorption process is the cost of adsorbents, which ultimately causes the expensive wastewater treatment application. One of such low cost adsorbent mostly used for the water treatment application is the chitosan. Chitosan is an amino polysaccharide, biomaterial obtained as an alkaline deacetylation product of chitin which is an exoskeleton part of crustacean's family such as prawns, crab, shrimps, krill, insects etc. [5]. This biopolymer used as an excellent adsorbent for the uptake of transition heavy metal ions and dyes.

The present study concerns batch removal of Pb (II) ions as a function of various parameters such as pH, adsorbent doses, agitation time and initial Pb (II) ions concentration. The batch adsorption experimental data were fitted to Langmuir and Freundlich isotherm models. The kinetics of adsorption was determined based on the pseudo first order and pseudo second order kinetics mechanism.

Experimental

Synthesis of CHB adsorbent

chitosan was dissolved in acetic acid solution followed by heating at 40–50 °C for some time. The mixture then cooled and dropped into aqueous ammonia followed by stirring. Finally CHB were separated, rinsed several times with distilled water and oven dried at 70-80 °C.

Results and Discussion

Adsorption Isotherm

In present research work the adsorption experimental data was fitted into the most widely used Langmuir and Freundlich isotherm models.

Langmuir adsorption isotherm

The Langmuir equation can be expressed as follows

$$\frac{c_e}{q_e} = \frac{1}{q_0 b} + \frac{c_e}{q_0}$$

Where, c_e (mg/L) is equilibrium concentration of Pb (II) ions in solution. q_e (mg/g) is the amount of Pb (II) ions adsorbed per unit weight of adsorbent at equilibrium. q_o (mg/g) is the maximum adsorption amount. b (L/mg) is the Langmuir constant representing energy of adsorption.

Freundlich adsorption isotherm

The empirical Freundlich equation is expressed as

$$q_e = K_f c_e^{1/n}$$

Where, q_e (mg/g) is the amount of adsorbate adsorbed per unit mass of adsorbent. c_e (mg/L) represents equilibrium Pb (II) ions concentration in solution. K_f and n are the Freundlich isotherm constants indicating adsorption capacity and adsorption intensity respectively. The Langmuir and Freundlich parameters are shown in Table 1.

The correlation coefficient R^2 = 0.986 from Langmuir isotherm, was closer to unity, shows that the adsorption data better fitted to the Langmuir plot.

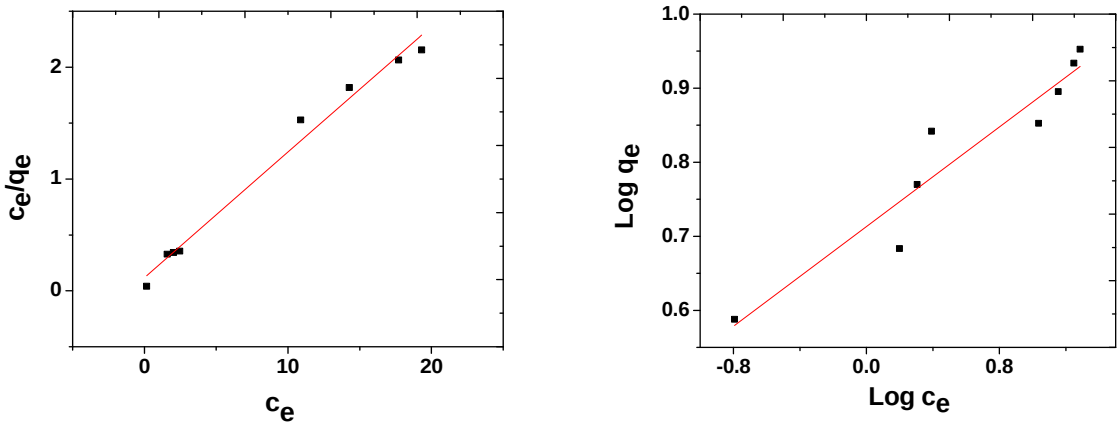

Fig. 1 Langmuir adsorption isotherm plot of c_e versus c_e/q_e and Freundlich adsorption isotherm plot of Log c_e versus Log q_e for adsorption of Pb (II) ions onto CHB.

Table 1. Langmuir and Freundlich adsorption isotherm parameters for Pb (II) ions adsorption.

Equilibrium model	Langmuir constants				Freundlich constants		
Parameters	q_o	b	R^2	R_L	K_f	1/n	R^2
Values	8.928	0.9492	0.98	0.0292-0.0090	5.1641	0.168	0.91

Adsorption kinetics

Pseudo first order kinetics

Rate equation for the pseudo first order [6] is generally expressed as $\frac{Dq_t}{d_t} = k_1 (q_e - q_t)$

Where, q_e and q_t (mg/g) were the adsorption capacities at equilibrium and at time t, respectively. k_1 (min^{-1}) is the rate constant of pseudo first order sorption.

The pseudo second order rate [7] expression is as follows

$$\frac{Dq_t}{d_t} = k_2 (q_e - q_t)^2$$

Where, q_e (mg/g) and q_t (mg/g) are the adsorption capacity of Pb (II) ions at equilibrium and at time t respectively. k_2 (g/(mg.min)) is the pseudo second order rate constant.

The linear correlation coefficient values of pseudo first order are comparatively lower than pseudo second order kinetics mechanism. Similarly the calculated q_e values are much higher than the experimental q_e values for 35 mg/L to 95 mg/L Pb (II) ions concentration and thus does not represents the good fit of pseudo first order with the experimental adsorption data. The results indicated that the adsorption of Pb (II) ions onto CHB follows pseudo second order kinetics.

Table 2. Pseudo first order, pseudo second order parameters for Pb (II) ions adsorption.

Lead (II)	Pseudo first order				Pseudo second order		
conc.(mg/L)	k_1	q_e	R^2	q_e (cal.)	k_2	q_e	R^2
95	0.0451	1.1094	0.990	8.55	0.0073	9.2592	0.99

Conclusions

The present research work explored the batch adsorption of Pb (II) ions onto chitosan hydrogel beads (CHB). The batch adsorption studies revealed the maximum uptake of Pb (II) ions was at pH 6 with CHB dose of 0.9 g/L in 140 minutes of contact time for 35 mg/L Pb (II) ions concentration. Langmuir adsorption isotherm better fitted with the adsorption experimental data with maximum uptake of Pb (II) ions as 8.928 mg/g. The kinetic study of Pb (II) adsorption onto CHB follows pseudo second order model.

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