KKU Res. J. 2014; 19(Supplement Issue): 224-228
http : //resjournal.kku.ac.th

Fixed Bed Column Study for Cr (VI) Removal from Aqueous Solution Using Durian Peel

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Abstract

The sorption of the chromium (VI) on durian peel was investigated in a fix bed column. Biosorption experiments were carried out to determine the influence of three different flow rates and bed heights. The column studies were conducted with a glass column with 2 cm diameter and 50 cm height. The results showed that the sorption capacity was strongly dependent on the flow rate and bed height. Also, the column performed well at the lowest flow rate and the highest bed height. As the flow rate increased, the breakthrough curve became steeper, the break point time and sorbed ion concentration decreased. The breakthrough time increased with increasing bed height. The optimal lowest sorbent usage rate was 0.022 g/ml and the minimum bed height values necessary to prevent the effluent solution concentration from exceeding 0.25 mg/l was 12.2 cm for the flow rate of 10 ml/min.

Keywords: biosorption, chromium (VI), fix bed column, durian peel

1. Introduction

One of environmental toxicants is Chromium (Cr). It is occurring in the environment difference oxidation states. However, only hexavalent chromium (Cr (VI)) and trivalent chromium (Cr (III)) are the most stable oxidation states in the natural environment. Both oxidation states of chromium are potentially harmful but Cr (VI) poses a greater risk due to its carcinogenic properties [1]. Chromium is widely used in electroplating, leather tanning, dye, cement and photography industries producing large quantities of effluents [2]. Thus, the discharge of Cr (VI) is regulated to below 0.25 mg/ l, while Cr (III) is regulated to below 0.75 mg/l in Thailand [3]. Therefore, it is necessary to eliminate it from the contaminated effluents before discharging to natural stream. Biosorption can be considered as an alternative technique for removing Cr (VI) ions from wastewaters. Most separation and purification processes that employ biosorption technology use continuous flow columns. Among the different column configurations, packed bed columns have been established as an effective, economical, and most convenient for biosorption processes [4-6]. The operation of the column should be terminated only when inlet solute concentration approximately equals that at the outlet. This is because complete column saturation, which results in S shaped breakthrough curve, is a function of the column flow characteristics, sorption equilibrium and mass transfer factors.

In general, all types of biomaterials have shown good biosorption capacities towards all types of metal ions. One such alternative is using biowastes as biosorbents, where has the dual advantage of waste reuse and low biosorbent cost. The use of low cost biosorbents is recommended since they are relatively cheap or of no cost, easily available, renewable, and show highly affinity for heavy metal. Durian is an economically important fruit. It is one of the popular fruits in Thailand, where the approximate production by Office of Agricultural Economics in 2010 is estimated to be 659,078 ton. The fruit is widely consumed fresh and in processed forms as dried fruits, marmalades, sweet candies, ice cream, and the others. Due to the high consumption of this fruit, significant amount of peels are expected to be discarded as agricultural wastes. The massive amounts of the peels (as waste products) are disposed, causing a severe problem in the community.

Therefore, durian peel has been used as chromium (VI) sorbent from aqueous solutions in a fixed-bed column process. The influence of several operational parameters has been analyzed (flow rate and bed height). The effect of empty bed contact time [EBCT] on the performance of the packed bed column was investigated.

2. Materials and Methods

2.1 Biosorbent preparation

Peel waste of durian was collected and was washed several times with deionized water, which was prepared by the technique of reverse osmosis, to remove heavy metals. The washed material was cut into small pieces (1-2 cm) and was dried at 60^{o}C in a hot air oven (Memmert Model 600) until they reached a constant weight, which was accomplished after 48 hrs. In the final stage this material was ground and screened with sieves having the cut of size of 0.850 - 1 mm.

2.2 Chromium (VI) solution preparation

Potassium dichromate ($K_2Cr_2O_7$) was dissolved in distilled water to obtain a standard solution of 1000 mg/l of Cr (VI). The Cr (VI) solution reacts in the presence of light. Therefore, the solution flask must be protected to avoid exposure to light.

2.3 Measurement of Cr (VI) concentrations

Column effluent samples of the concentration of Cr (VI) in the exit of the column were collected. Cr (VI) concentration was then determined using an indirect UV–vis spectrophotometric method based on the reaction of Cr (VI) and diphenyl carbazide, which forms a red–violet colored complex. The absorbance of the colored complex was measured in a double beam spectrophotometer at 540 nm wavelength [7].

2.4 Column experiments

Column experiments were conducted in a glass column with an internal diameter of 2 cm and a length of 50 cm packed with durian peel. The chromium solution at a known concentration was through the column of sorbent. The column studies were performed at pH 2 and room temperature. The breakthrough time has been chosen when the concentration of the effluent is 0.25 mg/l.

2.4.1 Effect of the flow rate

The sorption performance of durian peel was tested at various flow rates, 1, 5 and 10 ml/min. at inlet concentration of Cr (VI), 18.13 mg/l; pH 2; an biosorbent mass, 5 g (equivalent to 6 cm of bed height).

2.4.2 Effect of the bed height

The sorption performance of durian peel was tested at various bed heights, 1 g (1.1 cm), 5 g (6.0 cm) and 10 g (12.2 cm) at a flow rate of 10ml/min; pH 2; and inlet Cr (VI) concentrations of 18.13 mg/l.

3. Results and Discussion

3.1 Effect of the flow rate

To investigate at three different flow rates on the chromium (VI) biosorption by durian peel, the influent Cr (VI) ions concentration and bed height were held constant at 18.13 mg/l and 6.0 cm, respectively. Breakthrough plots between Ct/C0 versus time at different flow rate are given in figure 1 for three difference flow rates, 1, 5 and 10 ml/min. As can be seen in figure 1, as the flow rate increased, the breakthrough curve becomes steeper. The break point time and sorbed ion concentration decreases. As shown in table 1, the breakthrough time occurs at 125, 30 and 20 min for flow rate of 1, 5 and 10 ml/min, respectively; the respective EBCT are 18.86, 3.77 and 1.89 min. The reason for this behavior can be explained in the following way: when at a low flow rate, Cr (VI) ions had more time to contact with durian peel that resulted in higher removal of Cr (VI) ions in column. While increasing the flow rate, the results indicated that the biosorption capacity would reach the equilibrium value faster, which may cause a negative effect on the mass transferring efficiency of the Cr (VI) ions.

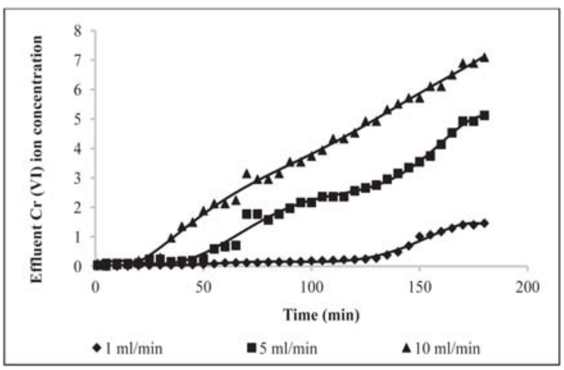

Figure 1. Breakthrough curves for Cr (VI) sorption onto durian peel at three different flow rates on fixed bed column

Condition: C_0=18.13 mg/l, bed height = 6.0 cm, pH = 2

The variation in the slope of the breakthrough curve may be explained on the basis of mass transfer fundamentals. The reason is that at higher flow rate the rate of mass transfer gets increases, i.e. the amount of Cr (VI) sorbed onto unit bed height (mass transfer zone) gets increased with increasing flow rate leading to faster saturation at higher flow rate [8]. These results were in agreement with other findings reported in literature [9-10]. The results obtained in the present investigation are in well agreement with the results obtained by Zulfadhly et al. [11] where macro fungus *Pycnoporus sanguineus* was used to adsorb heavy metals (Pb, Cu and Cd) from aqueous solution in fixed-bed column at various flow rates.

3.2 Effect of the bed height

Accumulation of Cr (VI) ions in the fixed-bed column is largely dependent on the quantity of biosorbent inside the column. In order to yield different bed heights, 1.0, 5.0 and 10.0 g of durian peel were added to produce 1.1, 6.0 and 12.2 cm, respectively. Figure 2 was the breakthrough curve at a constant flow rate of 10 ml/min and Cr (VI) inlet concentration of 18.13 mg/l. As can be seen in figure 2, the slope of breakthrough curve was slightly decreased with increasing bed height. The breakthrough time increased with increasing the bed height. As shown in table 2, the breakthrough occurs at nd, 20 and 45 min for bed height of 1.1, 6.0 and 12.2 cm, respectively; the

Table 1. The influence of three different flow rates on fixed bed column of Cr (VI) ion removal

Flow rate(ml/min)	$V_b(cm^3)$	Tb(min)	EBCT(min)	Usage rate(g/cm^3)
1	125	125	18.857	0.044
5	175	30	3.772	0.033
10	200	20	1.886	0.025

respective EBCT are 0.35, 1.89 and 3.83 min. So, sorbent bed height strongly affects the volume of the solution treated or throughput volume due to high contact time. It may be because of the reason that with the increase in bed height the sorbate has more time to contact with the biosorbent which in turn results into lower solute concentration in the effluent. Besides, an increase in the surface area of the biosorbent as the quantity of biomass packed in the column grows, and then, as the number of available sorption sites is greater. However, the increase in the quantity of biomass deposited in the column also resulted in a broadened mass transfer zone length [12], which makes breakthrough curves less steeper. This more gradual character of the curves as the bed height is increased implies that the bed was more difficult to be completely exhausted, as it has been showed in the literature [13-15].

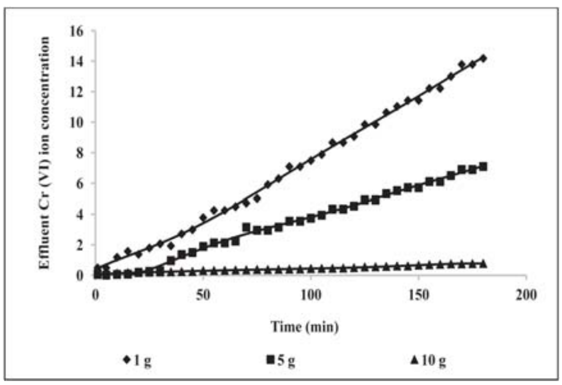

Figure 2. Breakthrough curves for Cr (VI) sorption onto durian peel at three different bed height on fixed bed column

Condition: C_0=18.13 mg/l, flow rate= 10 ml/min, pH = 2

The obtained values are shown in table 2 as a function of the EBCT, which represents the flow rate in the column. From Table 2, the optimal lowest sorbent usage rate was evaluated at 3.83 min contact time. This indicates that the ideal contact time in the column should not be less than 3.83 min in order to maintain the lowest usage rate (around 0.022g/ml).

4. Conclusion

This study indicated that the durian peel waste can be used with good performances as sorbent material in the removal process of Cr (VI) on fixed bed column. The result confirms that the breakthrough curves are strongly dependent on the flow rate and bed height. It was found to perform better with lower flow rate and higher bed height. As the flow rate increased and the bed height decreased, the breakthrough curve became steeper, the breakthrough time and sorbed ion concentration decreased. This waste reuse has the advantages in several aspects based on low biosobent cost and environmental pollution control. It will be more environmental friendly and a cost effective technique.

5. Acknowledgement

The authors thank the Ubon Ratchathani Rajabhat University for its financial support.

Table 2. The influence of three different bed heights on fixed bed column of Cr (VI) ion removal

Weight(g)	Bed height(cm)	Tb(min)	V_b(cm^3)	EBCT(min)	Usage rate(g/cm^3)
1.0	1.1	nd	-	0.346	-
5.0	6.0	20	200	1.886	0.025
10.0	12.2	45	450	3.834	0.022

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