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Predicting the dynamics and performance of a polymer–clay based composite in a fixed bed system for the removal of lead (II) ion

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ABSTRACT

A polymer–clay based composite adsorbent was prepared from locally obtained kaolinite clay and polyvinyl alcohol. The composite adsorbent was used to remove lead (II) ions from aqueous solution in a fixed bed mode. The increase in bed height and initial metal ion concentration increased the adsorption capacity of lead (II) and the volume of aqueous solution treated at 50% breakthrough. However, the adsorption capacity was reduced by almost 16.5% with the simultaneous presence of Ca^{2+}/Pb^{2+} and Na^{+}/Pb^{2+} in the aqueous solution. Regeneration of the adsorbent with 0.1 M of HCl also reduced its adsorption capacity to 75.1%. Adsorption of lead (II) ions onto the polymer–clay composite adsorbent in the presence of Na^{+} and Ca^{2+} electrolyte increased the rate of mass transfer, probably due to competition between cationic species in solution for adsorption sites. Regeneration further increased the rate of mass transfer as a result of reduced adsorption sites after the regeneration process. The length of the mass transfer zone was found to increase with increasing bed height but did not change with increasing the initial metal ion concentration. The models of Yoon–Nelson, Thomas, and Clark were found to give good fit to adsorption data. On the other hand, Bohart–Adams model was found to be a poor predictor for the column operation. The polymer–clay composite adsorbent has a good potential for the removal of lead (II) ions from highly polluted aqueous solutions.

Keywords: Fixed bed; Adsorption models; Polymer–clay composite; Regeneration; Breakthrough; Mass transfer zone

1. Introduction

The conventional method for assessing the sorption capacity of low cost adsorbents is batch adsorption studies. Batch adsorption is easily applied in the laboratory for the treatment of small volumes of effluents. However, it is not convenient for application on an industrial scale where large volumes of wastewater are continuously generated.

An industrial application of adsorption usually involves fixed bed adsorption columns where the adsorbate is continuously in contact with a given quantity of fresh adsorbent. Therefore, it is important to determine the column performance of any adsorbent that has proved promising in batch experimental studies. Fixed bed operations are widely used in wastewater treatment processes such as separating ions by an ion exchanger or removing toxic organic compounds by carbon adsorption (Gabaldon et al., 1996).

From extensive batch experimental studies, we have reported that polyvinyl alcohol–modified kaolinite clay (PVA–MKC) was a novel adsorbent which showed very good promise as an alternative adsorbent that would compete favorably with existing adsorbents used in the industry for the adsorption of Pb^{2+} and Cd^{2+} from aqueous solutions (Unuabonah, 2007). This is because of its high adsorption

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