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Axial mixing and mass transfer investigation in a pulsed packed liquid–liquid extraction column using plug flow and axial dispersion models

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ABSTRACT

In this research work, the volumetric overall mass transfer coefficient based on continuous-phase ($K_{oc}a$) and axial dispersion coefficients of phases (E_c, E_d) in a pilot Pulsed Packed Liquid Extraction Column (PPLEC) have been studied using plug flow model (PFM) and axial dispersion model (ADM). Experiments have been carried out using standard systems of water/acetone/toluene and water/acetone/n-butyl–acetate. Values of $K_{oc}a$ evaluated by ADM are greater than those of PFM by about 20% indicating that the axial mixing lowers the performance of PPLEC. It was found that the drop-size distribution is the main cause of the axial mixing in PPLEC. Increase in dispersed phase flow rate (Q_d), increases all $K_{oc}a$, E_d and E_c and the minimum values of both E_d and E_c and the maximum values of $K_{oc}a$ are in pulse intensity ranges of 0.8–1 cm/s. Finally, three empirical correlations are proposed for the prediction of these parameters which are in good agreement with the experimental data.

Keywords: Mass transfer coefficient; Pulsed packed column; Axial dispersion models; Liquid–liquid extraction

1. Introduction

Pulse column is a liquid–liquid contactor in which the rate of the mass transfer is enhanced by the hydraulic or pneumatic pulsation of the liquids in the column. A pulsed extraction column may contain ordinary packing, special sieve plates or sometimes alternated discs and doughnuts. In a packed column the pulsation disperses the liquids and eliminates channeling, so the contact between the phases is greatly improved. Wiegandt and Von Berg (1954) observed 30% reduction of required height of a packed column in case of pulse treatment. In PPLEC, insertion of packing and pulsation, advantageously diminish axial mixing but quantitative estimation for axial mixing is not reported in the literatures except in the work of Torab-Mostaedi and Safdari (2009).

In order to design or scale up an extraction column, it is essential to forecast the mass transfer behaviors using a suitable mathematical model. Usually mass transfer and axial mixing parameters will be optimized by introducing experimental solute concentration profiles into these models. Already many mass transfer models such as plug flow (PFM), axial dispersion (ADM), backflow and recently developed forward mixing model (Jie and Weiyang, 2000; Kumar and Hartland, 1999; Miyauchi and Vermeulen, 1963) have been studied. The first two ones (PFM and ADM) have a widespread use in extraction column modeling and simulations. However, much work has been done to recognize and quantify the departures from the ideal plug flow conditions caused by circulatory flow, small eddies, channeling, and velocity profile (Morales et al., 2007; Sleicher, 1959).

ADM, originally proposed by Danckwerts (1953), was a promising solution in which all of these factors were considered in terms of a single parameter named axial dispersion coefficient E. These parameters (E_d, E_c) can be experimentally determined by using the tracer injection techniques (Mak et al., 1991; Goebel et al., 1986) or from the experimental solute

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