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Modeling of arsenic, chromium and cadmium removal by nanofiltration process using genetic programming

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ABSTRACT

In this paper, genetic programming (GP) as a novel approach for the explicit formulation of nanofiltration (NF) process performance is presented. The objective of this study is to develop robust models based on experimental data for prediction the membrane rejection of arsenic, chromium and cadmium ions in a NF pilot-scale system using GP. Feed concentration and transmembrane pressure were considered as input parameters of the models. The ions rejection is considered as output parameter of the models. Some statistical parameters were considered and calculated in order to investigate the reliability of each model. The results showed quite satisfactory accuracies of the proposed models based on GP. The results also nominated GP as a potential tool for identifying the behavior of a NF system.

1. Introduction

One of the most serious environmental contaminants which recognized as threaten to human lives are heavy metals. Their higher toxicity, accumulation and retention in human bodies are the main problems that they make [1]. Arsenic, Chromium and Cadmium have been made wide attractive attention from environmentalist as one of the main toxic pollutants in drinking water.

Obviously, removal of these pollutants are kind of interest. Nanofiltration (NF) is a pressure-driven process which its characteristics fall among ultrafiltration (UF) and reverse-osmosis (RO) ones [2]. In fact, in comparison with UF and RO, NF allows obtaining higher fluxes than reverse osmosis and better rejections than ultrafiltration [3–6]. Because of its benefits, such as low energy consumption, high permeation flux, and unique separation capability for different valence ions, nanofiltration has been widely used in different applications, for instance, heavy metals removal, water softening, color removal and reduction of chemical oxygen demand (COD) and biological oxygen demand (BOD) [1,2,6–10]. However, for a successful implementation of the process it is necessary to obtain some information about the performance of a given membrane. On this basis, modeling plays an important role in description of a NF process and provides useful information about it.

Several efforts have been made to develop models that have a reasonably good description of a NF process. Many NF models based on extended Nernst–Planck equation have been presented so far. One of these models, which widely have been used, is Donnan-steric partitioning pore model (DSPM) [11–13]. This model describes the transport of ions in terms of porosity ratio, an effective membrane thickness and charge density. DSPM has undergone several modifications by taking into account the hindrance effect of the ions through the pores in the membranes [14], concentration polarization [15], and dielectric constant [16]. Some other models based on extended Nernst–Planck equation have been developed for description of a NF process in separation of heavy metals. Gomes et al. [6] analyzed the nanofiltration process for separating Cr (III) from acid solutions and the results were interpreted with a suitable mathematical model that includes the polarization effect and extended Nernst–Planck equation. Garba et al. [1] proposed a model in combination of the extended Nernst–Planck equation with the film theory. The proposed model was applied to predict cadmium salts rejection through a nanofiltration membrane and reasonably good results were obtained.

Kedem and Katchalsky [17] proposed a model which describes the transport of the solute through ultrafiltration, nanofiltration, and reverse osmosis membranes by irreversible thermodynamics. This model, which have used by many investigators [17–23], treats NF membranes as a gray box and characterizes them in terms of salt permeability and reflection coefficient.

The above mentioned mathematical models were derived from physical descriptions and understanding of NF process. These models usually are mathematically complex, computationally expensive and require detailed knowledge of the filtration process [22,24]. Therefore, alternative methods for description of a NF process by using available process data and extending it to a mathematical model, which can be applied simply on unavailable data,

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