Journal of Environmental Management 204 (2017) 311–317

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

The nickel ion removal prediction model from aqueous solutions using a hybrid neural genetic algorithm

Fatemeh Sadat Hoseinian [a], Bahram Rezai [a, *], Elaheh Kowsari [b]

[a] Department of Mining and Metallurgical Engineering, Amirkabir University of Technology, Tehran 158754413, Iran
[b] Department of Chemistry, Amirkabir University of Technology, Tehran 15916-34311, Iran

ARTICLE INFO

Article history:
Received 12 May 2017
Received in revised form
13 July 2017
Accepted 4 September 2017

Keywords:
Ni(II) removal
Ion flotation
Artificial neural network
Genetic algorithm
Sensitivity analysis

ABSTRACT

Prediction of Ni(II) removal during ion flotation is necessary for increasing the process efficiency by suitable modeling and simulation. In this regard, a new predictive model based on the hybrid neural genetic algorithm (GANN) was developed to predict the Ni(II) ion removal and water removal during the process from aqueous solutions using ion flotation. A multi-layer GANN model was trained to develop a predictive model based on the important effective variables on the Ni(II) ion flotation. The input variables of the model were pH, collector concentration, frother concentration, impeller speed and flotation time, while the removal percentage of Ni(II) ions and water during ion flotation were the outputs. The most effective input variables on Ni(II) removal and water removal were evaluated using the sensitivity analysis. The sensitivity analysis of the model shows that all input variables have a significant impact on the outputs. The results show that the proposed GANN models can be used to predict the Ni(II) removal and water removal during ion flotation.

1. Introduction

The wastewater of many industrial processes has large quantities of heavy metal ions that can be introduced in the environment. The wastewaters contain heavy metal ions (cations and anions) that are important from environmental and economic points of views. Ni(II) is one of the common hazardous heavy metal ions that usually exist in the cationic forms in wastewaters (Mahmoud and Lazaridis, 2015). In industrial wastewaters, Ni(II) toxic ions are usually discharged from various industries including stainless steel, non-ferrous alloys, alloy steels, foundry, plating, batteries and electroplating. This can cause many diseases such as nephrotoxic, pulmonary toxic, allergic skin, immunotoxic, carcinogenic agent and hepatotoxic for humans (Das et al., 2008; Hoseinian et al., 2015). The maximum admissible concentration of Ni(II) is 0.5 mg/L in drinking water. Thus, the Ni(II) ion removal to its allowable limit is necessary before wastewater discharge to the environment.

Flotation is successfully applied to treat the water and wastewater containing heavy metals. Several flotation techniques such as ion, precipitate and/or sorptive flotation are successfully used to remove heavy metal ions (Deliyanni et al., 2017). The ion flotation process application for the removal of many heavy metal ions in the periodic table is investigated in the literature, which indicates its high efficiency for removal of various anions and cations from wastewater (Doyle, 2003; Polat and Erdogan, 2007; Liu and Doyle, 2009; Shakir et al., 2010; Bodagh et al., 2013). Ion flotation involves the surface-inactive ion removal using collector ions with an opposite charge of desired ions. Then, the complexes of the collector-metal ion are removed by gas bubbles rising through the solutions. The ion flotation efficiency is directly proportional to both ion removal and water removal due to true flotation and entrainment. Thus, one of the effective factors on the flotation efficiency is water removal during the flotation process that has a significant effect on true flotation. The most efficiency of ion flotation can be considered with high ions removal and low water removal during the process (true flotation) (Polat and Erdogan, 2007; Hoseinian et al., 2017b). Numerous studies of ion flotation are investigated in the literature, but a majority of them do not evaluate the effect of water removal during the process. Thus, water removal is also evaluated in this study.

Artificial neural networks (ANNs) have been widely applied to model and control non-linear systems. An accurate representation of the process based on the relationship between input and output data can be obtained during the ANN training phase without a

* Corresponding author.
E-mail address: rezai@aut.ac.ir (B. Rezai).

http://dx.doi.org/10.1016/j.jenvman.2017.09.011

rigorous mathematical model development and precise understanding (Mohanty, 2009). Aber et al. recently used ANN to predict the Cr(VI) removal from polluted solutions using electrocoagulation (Aber et al., 2009). An application of ANN for the prediction of Cu(II) ion removal from industrial leachate using adsorption has been reported by Gamze Turan et al. (Turan et al., 2011). More recently, a hybrid artificial neural network–genetic algorithm for the optimization of lead ion removal by intercalated tartrate-Mg–Al layered double hydroxides has been reported by Yasin et al. (Yasin et al., 2014). Mohanty also used the ANN based model predictive controller to control the interface level in a flotation column. The results showed that the performance of the ANN model was better than other conventional controllers (Chelgani et al., 2010). ANN models are successfully used for optimization, prediction and controlling in the flotation process.

Prediction of Ni(II) removal using ion flotation is difficult due to the high interaction among variables. No study evaluated the prediction of the removal of Ni(II) and water during the process using ion flotation in the literature. In this study, the hybrid neural genetic algorithm (GANN) model was developed to predict the Ni(II) removal and water removal separately during ion flotation. The effective parameters on the process efficiency including pH, collector concentration, frother concentration, impeller speed and flotation time were studied and considered as inputs in the models.

2. Materials and methods

2.1. Data set

Sodium dodecylsulfate (SDS), purchased from Merck, was used as the collector. Nickel nitrate ($(Ni(NO_3)_2 \cdot 6H_2O)$ was obtained from Merck. Dowfroth 250 (DF250), purchased from Dow Chemical, was used as frother. The solution pH was adjusted using HCl and NaOH (Merck). The initial ion concentration of Ni(II) ions was constant at 10 mg/L in the experiments. Flotation experiments were carried out at a Denver laboratory flotation cell with 1 L capacity. The percentage of Ni(II) ions in the solution was specified by atomic absorption spectrometry (AAS).

2.2. Effect of parameters

The optimal chemical conditions were initially determined by considering the effective factors on the ion flotation including collector concentration, frother concentration and pH solution by the response surface method (RSM) based on central composite design (CCD). In optimum conditions (pH = 9.7, frother concentration = 20 ppm and collector concentration = 0.1351 ppm), Ni(II) removal and water removal were obtained at 100% and 37%, respectively. Then, the optimal values of impeller speed and flotation time were evaluated in the optimal chemical conditions. The impeller speed of 800 rpm and flotation time of 8 min were determined as optimal values. In order to develop the new models to predict the Ni(II) removal and water removal, 67 data of the Ni(II) ion flotation process were collected in different experimental conditions.

The effect of the main factor on the Ni(II) removal and water removal is presented in Fig. 1. The results show that the Ni(II) removal increased with increasing the impeller speed, collector concentration and time until their optimal values and subsequently remained in the constant value of 100%. It increased with an increase in pH from 3 to 5.5 and then decreased at a pH of 8. The maximum Ni(II) removal was obtained at a pH of 9.7. The results

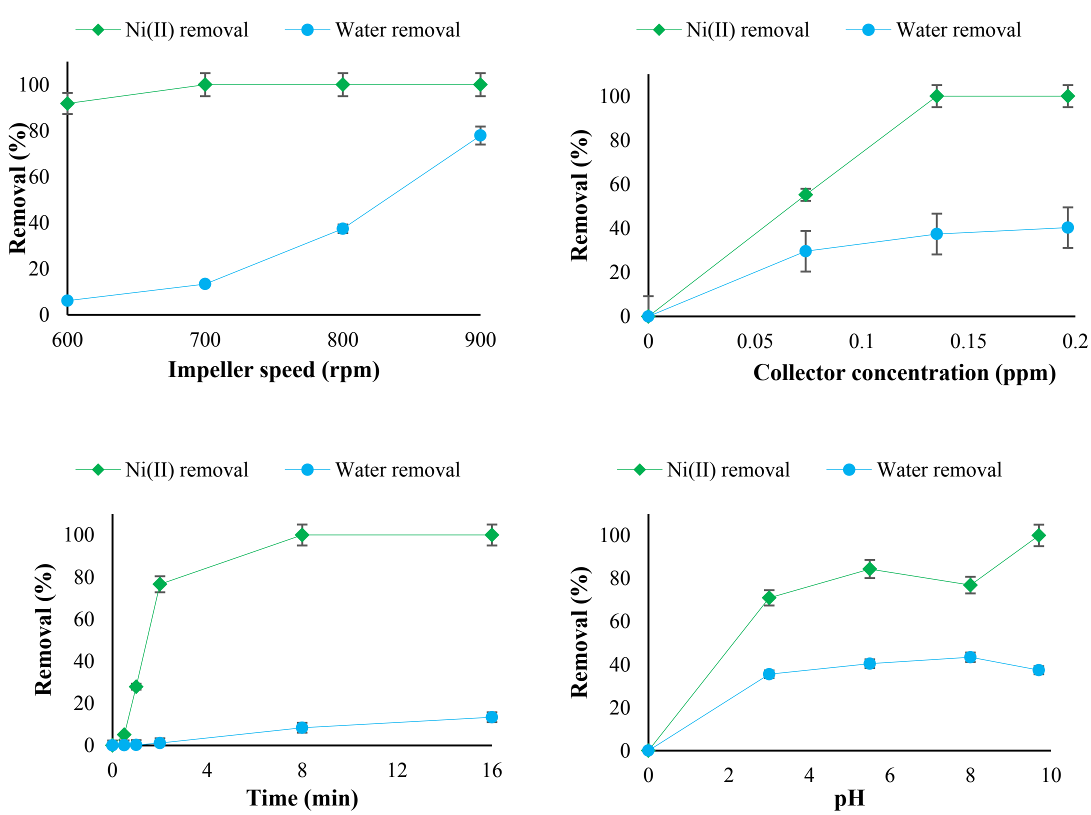

Fig. 1. The effect of main factors on the Ni(II) removal and water removal.