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Recovery prediction of copper oxide ore column leaching by hybrid neural genetic algorithm

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Abstract: The artificial neural network (ANN) and hybrid of artificial neural network and genetic algorithm (GANN) were applied to predict the optimized conditions of column leaching of copper oxide ore with relations of input and output data. The leaching experiments were performed in three columns with the heights of 2, 4 and 6 m and in particle size of <25.4 and <50.8 mm. The effects of different operating parameters such as column height, particle size, acid flow rate and leaching time were studied to optimize the conditions to achieve the maximum recovery of copper using column leaching in pilot scale. It was found that the recovery increased with increasing the acid flow rate and leaching time and decreasing particle size and column height. The efficiency of GANN and ANN algorithms was compared with each other. The results showed that GANN is more efficient than ANN in predicting copper recovery. The proposed model can be used to predict the Cu recovery with a reasonable error.

Key words: leaching; copper oxide ore; recovery; artificial neural network; genetic algorithm

1 Introduction

Heap leaching is a hydrometallurgical method that is used to leach low grade minerals such as copper, gold, nickel and zinc. In this method, piles of crushed ore are irrigated with various chemical solutions to leach and extract valuable minerals [1]. The effects of metallurgical parameters (such as particle size, porosity and permeability of ore, temperature, column height, solvent concentration, leaching time, solution flow rate, and mineralogy and chemistry of ore) on the process are usually studied using column leaching test. The results of column leaching are used in the optimization, planning, control and design of heap leaching [1−8].

Many experimental and modeling studies such as analytical and mathematical modeling have been carried out to gain a better understanding of the heap leaching process and its operation [9,10]. However, little research has been conducted with the aim of optimizing the process. Recently, analytical models have been used for planning, optimization, design and control of the heap leaching process and a mathematical model for heap leaching has been presented that was useful for designing and scaling up the processes [11]. MELLADO et al [7,12] also used an analytical model to optimize the flow rates on copper heap leaching. In this regard, they carried out an analytical–numerical method to solve a heap leaching problem of one or more solid reactants from porous pellets. VEGLIO et al [13] evaluated the effect of some main parameters on the column leaching of a manganese dioxide ore using fractional factorial design. CHELGANI and JORJANI [14] used the artificial neural network for the prediction of Al_2O_3 leaching recovery in the Bayer process. They studied the relationship between the recoveries of leaching and the chemical modules of bauxite fed to the process using methods of ANN and regression. They noted that the proposed ANN could be used for the prediction of Al_2O_3 leaching recovery.

The objective of this study is to obtain optimum conditions for column leaching by testing main parameters involved in the leaching process. Artificial neural network (ANN) model is developed to predict the recovery of column leaching, by taking into account four leaching parameters as inputs to the model, such as column height, particle size, acid flow rate and leaching

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time. In order to improve prediction accuracy, the genetic algorithm (GA) is incorporated in the training phase of a network, involving two objectives: the mean squared error (MSE) and determination coefficient (R). The process data are used for the recovery prediction of Cu column leaching using ANN and hybrid of ANN and GA.

2 Materials and methods

2.1 Data sets

Tests were performed on copper oxide ore obtained from Tarom deposit, Zanjan, Iran. Sulfuric acid with concentration of 20 g/L was used for ore leaching, and LIX98N solvent was used for extraction of copper from leach liquor.

The initial sample ore was split into two samples. One was crushed to less than 50.8 mm by a jaw crusher and the other to less than 25.4 mm. After blending, representative samples were collected for particle size distribution analysis, chemical analysis, and mineralogical characterization. Screen analysis was performed by mechanically shaken Tyler sieves.

Chemical analysis of elements was carried out by ICP-emission spectrophotometry. The X-ray diffraction (XRD) analysis of ore was used in order to determine the mineralogical species. The crushed samples were agglomerated with 30% of their maximum sulfuric acid consumption (30 kg/t) and then charged within the columns.

Sulfuric acid solutions were freshly prepared as needed, every three or four days. Leaching solutions were fed by peristaltic pumps. Every other day of leaching, a given amount of pregnant leach solution (PLS) sample was taken and quantitatively analyzed for copper and free sulfuric acid. Copper was extracted from PLS by the solvent extraction method using LIX984N and the raffinate solutions were circulated after adjusting its acid concentration. The leaching experiments were stopped when the copper concentration of PLS reached 0.1%. The experiments with 2, 4 and 6 m columns were completed within 78 d.

2.2 Effect of parameters

The results showed that the copper recovery has an inverse relation with the column height and particle size, and a direct relation with the leaching time and the acid flow rate. The obtained copper recoveries in the columns with the heights of 2, 4 and 6 m and particle size of 25.4 and 50.8 mm during column leaching over 78 d are shown in Table 1. One of the important factors in the leaching of copper from ore is time. Copper in the ore undergoes physical and chemical reactions. Figure 1 shows that the copper recovery increases with increasing

Table 1 Effect of column height and particle size on copper recovery

Column height/m	Particle size/mm	Recovery/%
2	25.4	78.63
2	50.8	44.21
4	25.4	46.10
4	50.8	18.39
6	25.4	34.09
6	50.8	12.66

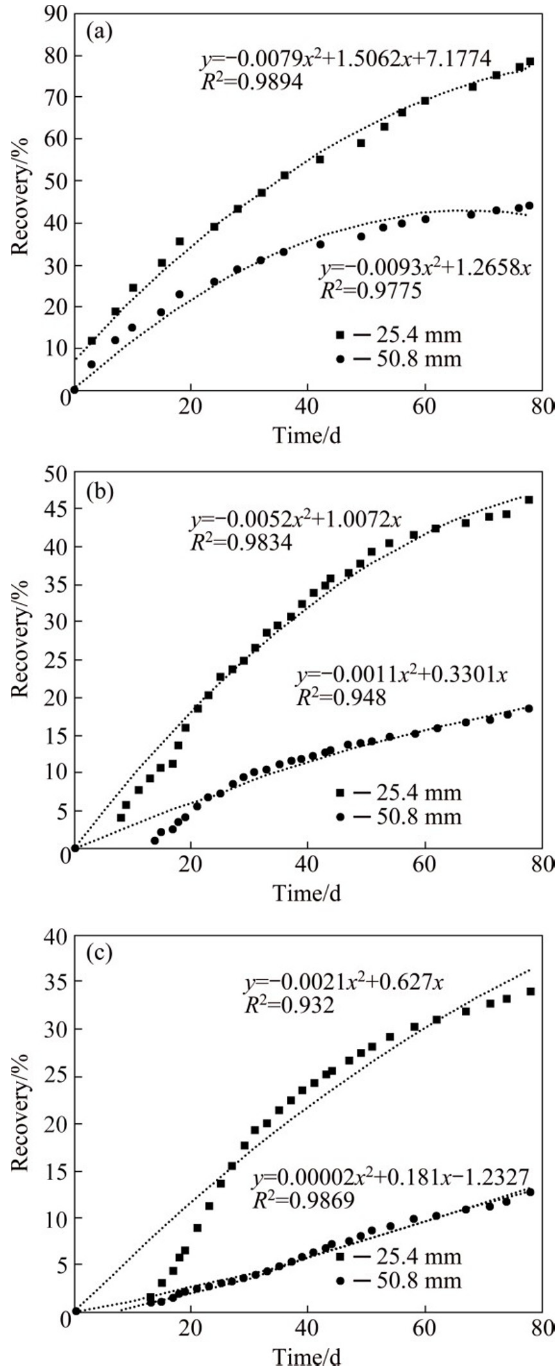

Fig. 1 Effect of time and particle size on recovery of copper during column leading: (a) Column height=2 m; (b) Column height=4 m; (c) Column height=6 m