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Best combination of e-wastes to recover maximum amount of Cu

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Abstract

In bioleaching process cyanidation of gold is difficult because of the ready formation of copper cyanide complexes. To solve this problem removing copper is considered in this study. Six kinds of e-waste including MPPCBs, CPCBs, TVPCBs, FPCBs, COPCBs, and CPU was prepared. 31 experiments was designed and performed at 250 ml Erlenmeyer flasks containing 100 ml solution with 10% inoculum, at 30 ℃ and 130 rpm. Pulp density was adjusted at 15 g/l. After 20 days incubation the incubation was stopped and the recovered copper was analyzed using inductively coupled plasma optical emission spectroscopy (ICP-OES). The D-optimal mixture experimental design was conducted using *A. ferrooxidans.* The optimum portion suggested by the software for CPCBs, MPPCBs, TVPCBs, COPCBs, FPCBs, and CPU is 10%, 15%, 50%, 10%, 10%, and 5% respectively.

Keywords: E-waste, Cu recovery, D-optimal mixture

Introduction

Nowadays with advancements in the electronic instruments, electronic waste (e-waste) is one of the fastest growing wastes produced [1]. The concentration of gold, silver, palladium, and copper in mobile phone is about 340 ppm, 3500 ppm, 140 ppm, and 130000 ppm respectively [2]. The amount of these metals in e-waste is more than 10 time higher than natural mine. Microbial treatment is low cost, low hazardous emissions and low-tech systems [3]. *A. ferrooxidans* is the most important microorganism in bioleaching process (Ilyas, 2010). In bioleaching process cyanidation of gold is difficult because of the ready formation of copper cyanide complexes during gold bioleaching [4]. Removing copper is considered in this study. The purpose of this study was to determine the effect of presence of different kinds of e-wastes and mixture interaction on the copper recovery and obtain the best combination of e-wastes to recover maximum amount of Cu. Mixture design was conducted to find the optimal composition of different kinds of e-wastes.

Experimental

Six kinds of e-waste including MPPCBs, CPCBs, TVPCBs, FPCBs, COPCBs, and CPU was prepared from a e-waste recycling company named Pars Charkhesh Asia located in Tehran, Iran. Then samples were micronized to less than 150 micron using a micronizer (Herzog, West Germany). The concentration of copper in different kinds of e-wastes was shown at Table 1. A pure culture of *Acidithiobacillus ferrooxidans* was prepared and cultured at 9k medium.

The D-optimal mixture experimental design was conducted using Design Experiment (10.0.4) Software. It was used to study the relationships between the proportions of different kinds of e-wastes and responses. The experimental design consisted of 31 experiments in total with six components: X1, the percentage of CPCBs; X2, the percentage of MPPCBs; X3, the percentage of TVPCBs; X4, the percentage of FPCBs; X5, the percentage of COPCBs; and X6, the percentage of CPU. In this design the proportion of each e-waste in the mixture was restricted to be from 0 to 50% such that $Z_1 + Z_2 + Z_3 + Z_4 + Z_5 + Z_6 = 100$, $0 \leq Z_i \leq 50$, i= 1, 2, 3, 4, 5, 6 which Z is proportion of each e-wastes. 31 experiments was designed and performed at 250 ml Erlenmeyer flasks containing 100 ml solution with 10% inoculum, at 30 ℃ and 130 rpm. Pulp density was adjusted at 15 g/l. After 20 days incubation the incubation was stopped and the recovered copper was analyzed using inductively coupled plasma optical emission spectroscopy (ICP-OES).

Table 1: Cu concentration in different kinds of e-wastes

MPPCBs	CPCBs	TVPCBs	FPCBs	COPCBs	CPU
481284.3	617315.22	454558.01	391868.41	398644.76	305078.87

Results and discussion

A modified quadratic model was suggested by the software which has a model p-value of 0.0075, p-value of lack of fit 0.9755 and R-square of 85%. Figure 1(a) shows the normal plot of residuals for Cu recovery is normally distributed, as they lie on diagonal line which valid no deviation of the variance. Figure 1(b) shows the predicted value calculated from the statistical model versus actual values obtained from experiments. The presence of the points around diagonal line show relatively good agreement.

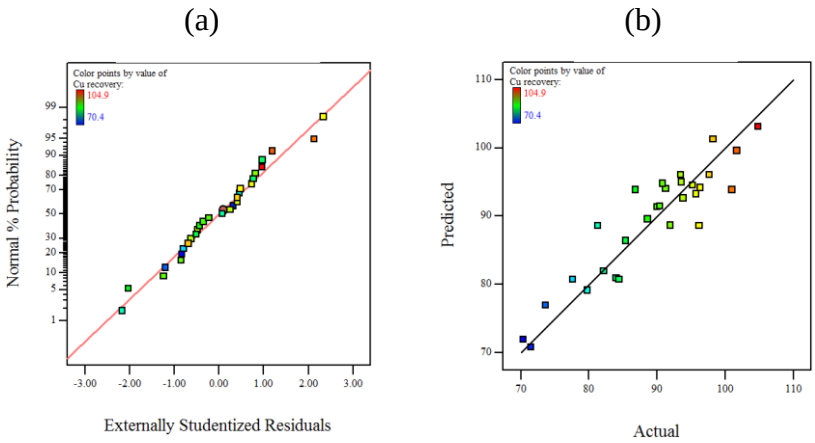

Figure 1: (a) Normal probability versus externally studentized residuals (b) Predicted vs. actual data

Eq. 1 shows the predicted model for Cu recovery.

Cu recovery = -155.58927A +111.38543 B +159.50197C +80.70657D +127.34997E +73.36380F +104.90998AB +199.73045AC +384.21528AD +365.99185AE +511.43952AF -218.60217BE +44.83197BF -172.80437CD -192.28098CE -165.22888CF +65.41468DF (1)

where A, B, C, D, E, F, and E are CPCBs, MPPCBs, TVPCBs, COPCBs, FPCBs, and CPU respectively. Mixture contour plots provided a two dimensional view are presented at figure 2. In contour plots all points located in the same shade regions connected with contour lines show

the same amount of copper recovery. These plots predict the value of Cu recovery at different portion of different kinds of e-wastes. All of the parts of this figure is drawn at 35% of MPCBs and different portion of CPCBs. Figure 2(a) drawn at 0% of motherboards (or CPCBs) presented the area with highest Cu recovery was located on the maximum amount of CPU and COPCBs portion. The lowest amount related to increasing FPCBs. Increasing the portion of CPCBs to 25%, maximum amount of Cu recovery decrease to less than 90% at Fig2(b). Increasing the portion of CPCBs to 50%, CU recovery decreases to less than 21%.

The optimum portion suggested by the model for CPCBs, MPPCBs, TVPCBs, COPCBs, FPCBs, and CPU is 10%, 15%, 50%, 10%, 10%, and 5% respectively.

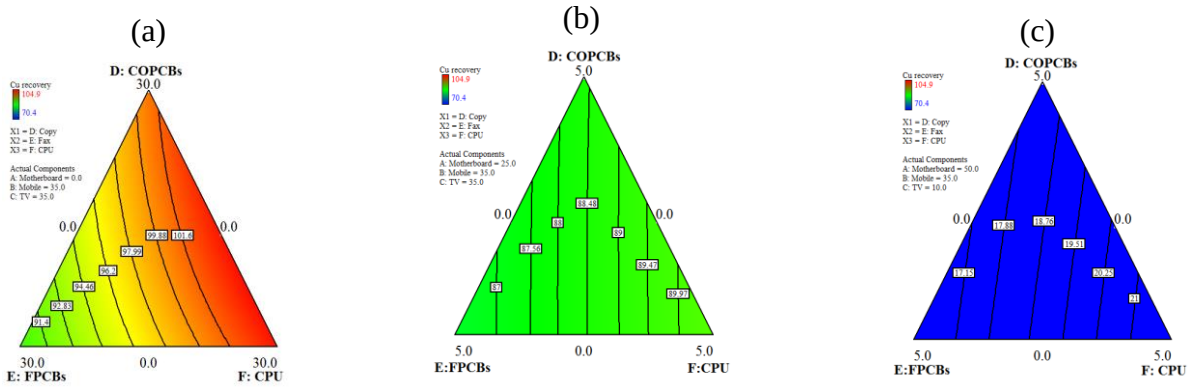

Figure 2: contour plots of Cu recovery at different portion of CPCBs (a) 0% (b) 25% (c)50%

Conclusions

In this study 6 kinds of e-waste was selected and Cu recovery in different portion of each kinds of e-wastes was examined. D-optimal mixture was used to define in what combination of e-waste maximum amount of copper extracted to reduce the negative effect of copper on gold recovery. The analysis of variance proves with increasing CPCBs the Cu recovery decrease. The presence of TVPCBs leads to maximum Cu recovery. The optimum portion suggested by the model for CPCBs, MPPCBs, TVPCBs, COPCBs, FPCBs, and CPU is 10%, 15%, 50%, 10%, 10%, and 5% respectively.

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