Biological leaching of plating residue using *Penicillium simplicissimum*

S. Nikfar, S. M. Mousavi*, N. Bahaloo-Horeh

Biotechnology Group, Chemical Engineering Department, Tarbiat Modares University, Tehran, Iran
mousavi_m@modares.ac.ir

Abstract

The management of industrial wastes is an important aspect of environmental engineering that not paying attention to it can cause so many problems including loss of valuable metals, pollution of the environment and human health risks. Among them, plating residue (PR) is classified as hazardous waste. Biological leaching is an efficient method of recovering metals from PR and can decrease heavy metal toxicity. In this research, at first, the optimal culture medium among four culture mediums (Czapek Dox Broth, Czapek Dox Broth-modified, Bosshard and Malt extract) was investigated. Finally, Bosshard was chosen as appropriate culture medium for leaching of PR. In the next stage, Bioleaching of Ni, Cr, and Cu from PR was conducted in different pulp density of 5, 10, 20 and 40 g/L. Eventually, the highest recovery of heavy metals (Ni: 186000 mg/kg, Cr: 45000 mg/kg and Cu: 12000 mg/kg) happens in the pulp density of 5 g/L.

Keywords: Plating residue, Heavy metals, Bioleaching, *Penicillium simplicissimum*.

Introduction

Plating residue (PR) is a byproduct formed by the metal plating industry which contains heavy metals such as zinc, chromium, copper, nickel, and iron, etc. The residue is classified as hazardous waste, so the storage and disposal are very expensive [1]. Therefore, in order to have both sound protection of environment and reuse of heavy metals from waste, a green approach for recovery of heavy metals from PR is of great importance. In recent decades, several methods for the removal and recovery of heavy metals have been established. They contain chemical precipitation [2] membrane separation [3], ion exchange [4] and microbiological techniques [5, 6].

Biohydrometallurgy is one of the profitable and effective green technologies used to recovery of metals from solid waste. The biohydrometallurgical process of solid waste is close to natural biogeochemical metal cycles and decreases resource demands such as minerals, landfill space, and energy [7]. Bioleaching is a specific method for biohydrometallurgy. It is based on microorganisms' ability to convert insoluble solid compounds into soluble elements that can be recovered. Secretion of microbial metabolites (such as organic and inorganic acids) cause to leach the metal from the waste [8]. Fungi have benefits over bacterial leaching, such as the ability to grow in a broad range of pH, tolerate poisonous substances and work at faster rates
of leaching [9]. Therefore, in this work, leaching of PR was conducted by *Penicillium simplicissimum*.

**Experimental**

**Preparation of PR**
PR studied in this work was supplied from metal plating industries in Tehran, Iran. The collected sample was dried at room temperature and then the powder was screened through mesh No. 200 (<75μm). The acid digestion method was used to establish the metal content of PR. The elemental composition of PR was Cr: 279400, Cu: 29500, Ni: 1900, Al: 197, Zn: 140, Mn: 22 and Ag: 17 mg/kg.

**Fungi inoculum preparation**
*Penicillium simplicissimum* (20019 BBRC) was obtained from the Iranian Research Organization for Science and Technology (IROST) in Tehran, Iran. The fungi were cultured on a 3.9% (w/v) potato dextrose agar plates and incubated in an incubator at 30 °C. The conidia were washed from the surface of the plates using sterile distilled water after seven days of incubation. The appropriate concentration of spore suspension (1×10^7 spore/mL) was obtained with diluting using sterile distilled water.

**Choice of appropriate culture medium**
The most suitable culture medium for the bioleaching process is the medium where the pH is lowest and the acid concentration is highest. In order to select the optimum culture medium for *Penicillium simplicissimum*, Czapek Dox Broth (sucrose: 30 g/L, NaNO₃: 3 g/L, K₂HPO₄: 1 g/L, MgSO₄·7H₂O: 0.5 g/L, KCl: 0.5 g/L, FeSO₄·7H₂O: 0.01 g/L), Czapek Dox Broth-modified (sucrose: 30 g/L, NaNO₃: 3 g/L, K₂HPO₄: 1 g/L, MgSO₄·7H₂O: 0.5 g/L, KCl: 0.5 g/L, FeSO₄·7H₂O: 0.01 g/L, yeast extract: 2 g/L), Bosshard (sucrose: 100 g/L, NaNO₃: 1.5 g/L, KH₂PO₄: 0.5 g/L, MgSO₄·7H₂O: 0.025 g/L, KCl: 0.025 g/L, yeast extract: 1.6 g/L) and malt extract were studied. To investigate the pH changes, 1 mL of spore suspension was added to 100 mL of each culture medium and incubated for 11 days at 30 °C and 130 rpm in a shaker-incubator.

**Bioleaching experiments**
Bioleaching assessment was conducted in different pulp density of 5, 10, 20 and 40 g/L. 1 mL of prepared spore suspension with the desired amount of PR was added to 100 mL of selected culture medium. All bioleaching experiments were done in 250 mL Erlenmeyer flasks at 30 °C and 160 rpm. After 10 days, all Erlenmeyer flasks were filtered with Whatman 42 filter paper and the filtrate was subjected to ICP analysis to determine the recovery of target metals (Cr and Ni and Cu).

**Analytical Methods**
Inductively coupled-plasma optical emission spectrometry (ICP-OES) (Spectro Arcos, Germany) was used to calculate the metals concentration in bioleaching filtrates. To measure the pH of medium, a digital pH meter (p25, ISTEK, South Korea) was used. An orbital shaker-incubator (Wise Cube, South Korea) was used during the bioleaching process to set temperature and rotate rate.
Results and discussion

pH change in culture mediums

The pH changes in the medium of Czapek Dox Broth, Czapek Dox Broth-modified, Bosshard, and malt extract are reported in Fig. 1. According to the results, *Penicillium simplicissimum* was unable to change the pH in the Czapek Dox Broth and the pH remained close to 7 until the 10th day. The pH value in the Czapek Dox Broth-modified was ascended from the 2nd day and finally on the 6th day reached 8.66. Objective observation of the fungal degradation, as well as the alkalization of pH, attests to the cell wall lysis and the release of intracellular metabolites into the culture medium [10]. Through Bosshard and malt extract, Bosshard was able to lower the pH greater. Therefore, the Bosshard was selected as the optimal culture medium for *Penicillium simplicissimum*.

![Fig. 1](image_url)

*Fig. 1: The pH change over time for Czapek Dox Broth, Czapek Dox Broth-modified, Bosshard, and malt extract.*

Heavy metals recovery from PR

Metals recovery after 10 days of incubation is shown in Fig. 2. According to the results, the recovery of metals decreases as pulp density increases. The main reason for this is the inability of the fungus to grow well at higher pulp densities of PR because of higher concentrations of heavy metals [11]. So, the highest recovery of metals (Ni: 186000 mg/kg, Cr: 45000 mg/kg and Cu: 12000 mg/kg) is in pulp density of 5 g/L. Moreover, the recovery of Ni by *Penicillium simplicissimum* from PR is higher than Cr and Cu. It means that *Penicillium simplicissimum* has the ability to recover Ni in high quantities.
Conclusions
In this work, the ability of *Penicillium simplicissimum* to leach heavy metals of PR in optimum culture medium was examined. Through four culture mediums (Czapek Dox Broth, Czapek Dox Broth-modified, Bosshard and malt extract), Bosshard was chosen as the optimum culture for secretion of organic acids as the main lixiviant in fungal leaching. Also, the recovery of heavy metals (Ni, Cr, Cu) was investigated at different pulp densities (5, 10, 20 and 40 g/L) from PR. The results show the highest recovery of the heavy metals (Ni: 186000 mg/kg, Cr: 45000 mg/kg and Cu: 12000 mg/kg) was obtained in pulp density of 5 g/L. Therefore, the leaching by *Penicillium simplicissimum* as an eco-friendly and cost-effective method is an effective way to recover heavy metals from PR.

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References


