- REPLY TO COMMENT ON PAPER

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The processing of a low-grade gold refractory sulfide ore by flotation-biooxidation-cyanidation route

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ABSTRACT

By depletion of high-grade and easy-to-treat gold ores and the increase in gold price, the extraction of gold from low-grade and refractory ores, such as sulfide ores has been given attention. Biooxidation is one of the efficient, relatively low-cost and environmentally friendly processes to enhance gold extraction by releasing fine gold encapsulated in sulfide phases. So, in this research, the efficiency of concentrate biooxidation-flotation system in increasing gold recovery from sulfide-refractory low-grade ores was investigated. Biooxidation experiments with mesophilic and moderate thermophilic microorganisms were conducted on the flotation concentrate. Finally, cyanidation experiments were conducted on the flotation concentrate, and biooxidized flotation concentrate. Gold recovery from non-biooxidized flotation concentrate was 63.59%, while it increased to 80.21% after biooxidation with mesophilic microorganisms and to 79.84% after biooxidation with moderate thermophilic microorganisms.

Keywords: *Biooxidation, Concentrate, Microorganism.*

1. Introduction

Currently, biotechnology has attracted much attention for gold recovery from sulfidic refractory gold ores (Natal'ya, Muravyov, & Kondrat'eva, 2010). In refractory gold ores, the gold particles are very fine and may be locked within particle boundaries or the structure of sulfide minerals, such as pyrite and arsenopyrite (Wang et al., 2020). Direct cyanidation method is not effective for extracting gold from refractory sulfide ores; therefore, a pretreatment process, such as roasting, pressure oxidation or biooxidation should be considered to liberate encapsulated gold from the sulfide minerals. Compared to other processes, biooxidation of sulfide refractory gold ores has several advantages, including low investment cost and environmental friendliness (Wu, 2018) (N. V. Fomchenko, Kondrat'eva, & Muravyov, 2016). In this process, metal sulfides are oxidized by iron- and sulfur-oxidizing microorganisms, forming soluble metal sulfates and sulfuric acid. Pyrite and arsenopyrite are well-known minerals that are easily biooxidized (Olson, 1994). During this process, microorganisms are catalytically used for oxidizing pyrite and arsenopyrite to release and expose gold for more processing (N. V. Fomchenko et al., 2016). In general, biooxidation for processing of refractory gold concentrate involves a typical flowsheet that includes crushing, milling, producing concentrate from the flotation process, followed by cyanidation and recovery of gold from biooxidized residues (Miller & Brown, 2016).

The operating temperature of a biooxidation process is very important because each microbial culture has its own optimal temperature for growth and oxidation (Muravyov, 2019). The bioleaching process of sulfide minerals involves two chemical and biological stages (N. Fomchenko et al., 2017). Nouhi et al. (2025) used acid drainage for the biooxidation of a high-grade refractory sulfide gold ore, and gold recovery increased from 73% (without biooxidation) to 99% (in the biooxidized residue). Beiranvand et al. (Beiranvand et al., 2023) investigated the effect of mechanical activation on the oxidation and extraction of gold from a high-grade flotation concentrate using mesophilic and moderate thermophilic microorganisms. Gold recovery from the non-mechanically activated and non-biooxidized concentrate was 83.9%, while after biooxidation this value reached 98.8%. Also, gold recovery from the activated but non-oxidized concentrate was 77.3%, which reached 97.6% after biooxidation.

By decreasing easy-to-treat gold ores, developing technologies and an increase in gold price, the recoverable grade of gold ores has decreased gradually. The development and optimization of biooxidation technology for increasing the recovery of gold from lean grade refractory sulfide wastes have not been previously well investigated. Flotation followed by biooxidation and cyanidation processesis one of the potential routes to treat such low-grade and refractory ores and tailings. So, in this research the ability of this strategy was evaluated to extract gold from the low-grade stockpiles of Mouteh gold mine.

2. Material and Methods

2.1. Material

Samples were taken from low-grade refractory sulfide gold ore stockpiles of Mouteh gold mine (Isfahan province, Iran). At first, the sample was homogenized. Crushing was performed in two stages to achieve the desired particle size. To achieve a particle size of -75 µm, the samples were ground using a rod mill with a ratio of 1:8 (1 kg samples: 8 kg rod) after crushing. The representative samples were used to analyze chemical and mineralogical parameters by XRD, XRF, and Fire Assay methods.

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