Extraction of Metals from Copper Tailings through Leaching

Subjects: Metallurgy & Metallurgical Engineering
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A copper tailing is a residue, product of the flotation of sulfide minerals, which contain a variety of elements that can be valorized. The extraction of metals from copper tailings consist of applying metallurgical techniques, such as acid leaching or magnetic concentration, to obtain a valuable product. Currently, this is an important objective, given that mining operations have increased the generation of tailings. Acid leaching is a process that consists of dissolving a solid material, such as a tailing, by applying an acid solution. This process forms two final products: an insoluble solid, rich in aluminosilicates, and an acid liquid solution with different metal ions. Both products may have different characteristics and can be used for subsequent applications.

Keywords: copper tailing ; leaching ; valorization

1. Introduction

Mining activity has increased due to worldwide demand, which rises as the world's population grows. This mineral extraction causes a significant waste generation, such as tailings and slags [1]. Mining production comes from all over the world. China, Australia, India, Brazil, South Africa, Russia, Canada, and Chile, are some countries with significant mining production [2]. Concerning Chile, the South American country sustains a crucial part of its economy in mining activity, mainly in the commercialization of copper obtained from the north of the country. However, with the increase in exploitation, ore grades are getting progressively lower, so mining operations have increased the amount of processed material. Hence, new concentrator plants and the expansion of the existing ones have increased the generation of tailings, which consists of a residue product of the flotation of sulfide minerals [3]. This has turned into a focus of ecological concern, given the delicate global environmental context, incentivizing many efforts to valorize this residue [4].

The valorization of tailings includes the utilization of the mineral matrix, as it contains mainly silica, and the recovery of residual metals, containing metals such as iron, copper, titanium, and many others [5]. Depending on the ore and the process used to treat it, it is possible to recover valuable elements from mine tailings. For example, copper sulfide ores are treated by flotation to recover copper, so the produced tailings contain mainly silicon oxide and a variety of metals [6]. In this regard, tailings may contain minerals such as quartz, orthoclase, magnetite, hematite, pyrite, and chalcopyrite, among others. Additionally, the total iron grade may be around 19%, due to their origin in the north of Chile [7][8]. In addition, given that tailings have already been mined and crushed, the treatment costs are considerably lower than primary ores, turning tailings into an economic raw material [5]. Therefore, studies have been made to use tailings as a construction material such as cement and to recover valuable elements such as iron through magnetic concentration and copper through bioleaching [7][9][10]. This reprocessing of mine tailings by different technologies is being explored to make mining operations more sustainable [11]. Acid leaching is widely used in mineral extraction and the recycling of valuable metals [12]. Sulfuric acid is the best-known and most conventionally used leaching agent; however, some studies recommend hydrochloric acid since the presence of chloride ions is advantageous for copper extraction [9][13][14]. In addition, many studies are focused on copper recovery from slags. Dimitrijević et al. worked with hydrochloric acid concentration below 2 M and combined it with hydrogen peroxide on copper slag samples [15]. Chen et al. performed a similar study using, also with copper slag, an 11 M concentration of hydrochloric acid at temperatures above 80 °C [13].

Chilean researches have carried out the characterization of an iron-rich tailing and the extraction of metals through leaching[16]. They obtained the tailing sample from a tailing dam placed in the north of Chile. Specifically, the sample was taken from the wall of the tailing dam using the trial pits technique. Their results showed that 80% of the sample is approximately below an ASTM 60 mesh, corresponding to 250 µm, meaning that the particle size distribution is fine. The tailing particles are irregular, and the composition is based on silicates and iron oxides. The composition was mainly quartz, magnetite, orthoclase, and albite. They determined that the tailing contains a total iron grade of 19%, which is a

high concentration of iron. They focused on some interesting elements such as copper, aluminum, calcium and magnesium. They found that if the tailing is submitted to acid treatment with hydrochloric acid (HCl), a liquid solution and an insoluble solid are generated. Both phases (liquid and solid) represent an opportunity to produce valuable secondary species [17][18]. Regarding the acid solution, it is rich in a variety of metals, specially iron. As for the insoluble solid, the samples had an irregular morphology composed mainly of silica, having mainly orthoclase, quartz, and albite.

2. Mineral extraction

Mineral extraction brings with it the generation of waste, such as tailings and slags. It is important to find new ways to treat these wastes and extract as many valuable species as possible. The variability of elements in each sample makes leaching a complex process. Hydrochloric acid leaching is an alternative when it is desired to extract more than one element at a time. The tailings of northern Chile contain an important amount of iron and other valuable species, such as copper and aluminum, which can be extracted through leaching with hydrochloric acid. The most relevant condition in this process is the acid concentration, due to its effect on the extraction of metals. Conditions can be selected according to the element that wants to be obtained, e.g., if a high iron extraction is wanted, a high acid concentration should be applied, while on the contrary, if a high extraction of aluminum is wanted, a low acid concentration should be used. The variables time and temperature do not show a relevant influence on the iron concentration, so it can be considered that it presents a constant behavior. Within the ranges studied, the conditions of 9 M acid concentration, 16 h reaction time, and a temperature of 25 °C were selected as the optimum leaching parameters. This process differs from traditional leaching by using hydrochloric acid instead of sulfuric acid; in addition, the raw material is a residue from a metallurgical process instead of mined ore. This proves that valuable elements such as iron, copper, and aluminum, along with calcium and magnesium, can be extracted from copper tailings for further valorization. The silicates obtained in the insoluble portion show low iron concentrations and could be used in other applications such as additives in the construction industry. It is important that these processes are circular, finding uses for waste such as tailings and also for the by-products of the tailing leaching. Environmental care is fundamental, so the production of by-products that are harmful to ecosystems must be avoided.

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