Economic Potential for reprocessing Copper Mine Tailings in Chile

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Abstract

Four copper mine tailings in Chile were investigated for their elemental and mineral composition, in order to evaluate the potential for economic reprocessing. The sample material, taken for processing had Cu-contents between 0.1 and 0.5 %. Copper was abundant in various primary (mostly chalcopyrite) and secondary (cuprite, atacamite, brochantite and chrysocolla) minerals. This report includes tests of laboratory size. Chemical sulfuric acid leaching was assessed in comparison to bioleaching. Copper bioleaching resulted in recoveries between 20 % and 70 %. For chemical leaching the recovery was 4 % to over 80 %. The recovery was strongly dependent on the mineralogical composition of the copper minerals. Secondary copper minerals were very scarcely abundant in the solid leaching residues. Using chemical leaching a very low copper recovery for one sample could be explained by the presence of the recalcitrant mineral chalcopyrite as the almost unique copper bearing mineral. In contrast, a significant copper bioleaching was found instead. Almost one third of all chalcopyrite grains showed clear signs of alteration investigated by scanning electron microscopy. Overall, the study shows that the economic potential for tailings reprocessing is strongly dependent on the composition of the valuable metals hosting minerals in connection with the applied processing technology.

Key words: Tailings, reprocessing, bioleaching, conventional leaching

Introduction

In Chile copper mining started in the middle of the 19th century. During the 20th century the country became one of the most important copper producing countries and since the early 1980s Chile is the most important copper producer with a share of more than 30 % of the world production (BGR data base). Concerning the production of waste,Chile is annually producing 350 million t of waste from copper mining and processing, according to conservative estimates. This lead to a total volume of 6.8 billion t over the last 30 years. These waste materials still contain copper and other metals and minerals of potential economic value. In this study we investigated the elemental composition, mineralogy and (bio)hydrometallurgy processing of mine waste tailings for an evaluation of their economic potential for reprocessing.

Methods

The Mineral Liberation Analysis is an automated mineral analysis, using back scatter electrons (BSE) from a scanning electron microscope (SEM). The **MLA** software automatically identified individual minerals at a high spatial resolution (0.005 mm) and quantified their respective proportions.

X-ray fluorescence (XRF) was used for measuring major and trace element composition.

Magnetic separation was applied on the concentrates obtained from the mechanical tailings processing on a wet shaking table (see below).

Concentrates were produced using **gravity sorting on a wet shaking table**. This technique uses the different densities of minerals to sort them. The higher the density of the material, the more the grains tend to be moved by the back and forth movement of the table, than by the water. As copper minerals have a higher density, compared to quartz and feldspar, they could be separated from these common rock-building, barren minerals.

For **bioleaching** experiments in shake flasks, 4 g of sample material were mixed with 200 ml medium. Additionally a 1 molar Fe^{2+} solution was added, to get a final concentration of 50 ppm Fe^{2+} for each assay. Each flask was inoculated with a mixed culture of acidophilic iron(II)- and sulfur-oxidizing bacteria (*Acidithiobacillus ferrooxidans* and *Acidithiobacillus thiooxidans*). The bioleaching was performed for approximately 28 days.

The **chemical leaching** experiments were done by IBZ-Salzchemie GmbH in Halsbrücke, Germany. Around 100 g of material was put in PVC beaker glasses, together with 1000 ml of water and a H_2SO_4 concentration of 49 g/L. Leaching was performed for 24 h.

Since tailings are highly heterogeneous bodies, hand driven core drills were performed, to sample 12 objects at several spots. The obtained samples were geochemically analysed (XRF). Based on these data four objects for taking a larger sample (about 20 kg) were choesen and gravimetric processing tests were carried out to produce concentrates. Subsequently both, the unprocessed tailings and the resulting concentrates were taken to execute conventional leaching and bioleaching tests.

Mineral Libaration Analysis (MLA) using an SEM was applied, in order to analyse the mineralogy of all samples, to obtain an optimal beneficiation scheme. The leaching residues were also analysed using MLA, to evaluate differences in the mineralogical composition of the ore minerals.

Results and Discussion

A total of 81 tailings samples were analyzed using XRF, during the survey sampling. The copper grade of the tailings varied between 0.1 % and 1.7 %. Further elements of interest were iron, gold, molybdenum and zinc.

This data and the tonnage of the tailings ponds was the basis to select four sites for a more detailed analyzes (Minera Carola, Minera Clarita, El Salado and Taltal). Around 20 – 25 kg of material were taken from each tailings dump and further processed in order to obtain concentrates and/or to do leaching tests.

Very large differences in the elemental and mineralogical composition of the tailings were discovered, causing an enormous effect on the Cu extractability that was revealed in laboratory studies of mechanical processing as well as bioleaching and chemical leaching.

For the El Salado tailings bioleaching gave a recovery of 60 % for the unprocessed sample. The copper grade of the sample taken for processing tests was only 0.4 %. Substantially less, than discovered during the survey samples (0.8 and 1.7 %). The tailings should be investigated in more detail to reveal the average grade of the material.

The Cu recovery of the tailings material from Taltal was high for both leaching techniques. With bioleaching around 70 % of the copper went into solution. This was substantially more than in the control experiment with slightly higher than 50 %. In the chemical leaching more than 80 % could be extracted. Iron, abundant as magnetite in this tailings pond, could be a significant by-product, as it can easily be concentrated, using magnetic separation.

Evidence of bioleaching was observed for about 1/3 of the analyzed chalcopyrite grains of the residue material. Nevertheless, the results exhibited a very poor recovery. If flotation should turn out to be feasible on the remaining chalcopyrite in the concentrates of Minera Carola, separate magnetite, chalcopyrite and pyrite concentrates could be produced. If all, including the pyrite concentrate, were marketable, a reprocessing could be of interest.

Tailings will be a marginal deposit in almost all cases from the economic point of view. Nevertheless for the tailings of Taltal our analysis resulted in an ore value of 24 US$/t (at a copper price of 6000 US$/t), not taking into acount credits from possible by-products like a magnetite concentrate. This is still a relatively low value compared to primary ore deposits, but the tailings are already crushed and milled, reducing the processing costs (energy needs). Additionally the production of a magnetite concentrate could substantially reduce the volume of the tailings, as the iron content was up to 53 % in one tailings pond.