Bioleaching of indium-bearing sphalerite under underground mining temperatures

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Extended Abstract

During the process of industrialization, the world-wide demand for resources steadily increases. Significant amounts of crucial metals and metalloids remain in low grade mineral deposits, however using conventional metal extraction methods on these minerals is not environmentally feasible. Minimization the pollution of water, soil and air, caused by conventional mining methods, can be achieved by alternative techniques such as biohydrometallurgy, namely bioleaching. This technique utilizes the activity of iron-oxidizing bacteria to catalyze the dissolution of sulfide minerals, in our case local sphalerite (ZnS) with traces of indium. Microbial metal extraction, especially from low-grade ores, is considered to be more eco-friendly and feasible compared to conventional methods like smelting.

Sulfide ores often contain sphalerite, pyrite or other compounds with complex matrices and mineralogical properties. There are studies reporting successful bioleaching of zinc sulfide in columns or in shake flasks [1,2]. Since different experimental conditions and specimens of ore material have been used in our experiments, the results vary to aforementioned studies. The aim of our project is an *in-situ* leaching site directly in the local mine *Reiche Zeche,* Freiberg.

Realization will facing us with several problems, first working under lower temperatures between 10 and 12°C and second dealing with indigenous microorganisms located in the mining field. This work revealed some preliminary results for leaching zinc and indium under mining conditions and will be fundamental for further approaches.

Commonly acidophilic mesophilic bacteria like *Acidithiobacillus ferrooxidans*, *At. thiooxidans* [3] and *Leptospirillum ferrooxidans* are applied for bioleaching. These iron- and/or sulfur-oxidizing bacteria grow optimally at low pH-values and temperatures around 30°C [4]. *At. ferrooxidans* and *L. ferrooxidans* derive their energy from oxidation of ferrous iron, *At. thiooxidans* and *At. ferrooxidans* are also able to oxidize reduced sulfur compounds like sulfides and elemental sulfur [5]. For the bioleaching of minerals with high concentrations of heavy metals such as copper, zinc, uranium, lead, silver, and gold, *At. ferrooxidans* was successfully used [6,7]. Most of these leaching applications were performed between 30°C and 60°C, e.g. tank or heap leaching. On the one hand the processes are much more effective at higher temperature, and second, the heat is often produced endogenously.

In contrast, our aim will be an *in-situ* leaching application directly in an underground mine site of mine *Reiche Zeche*, where the prevalent temperature is between 10 and 12°C, constantly. Hence, in this work leaching applications were performed at 11°C. Furthermore we didn´t performed our tests with pure cultures, but with mixed cultures originating directly from mine-waters at temperatures of about 11°C.

This gives a competitive edge, to work with indigenous microorganisms, which are adapted to low temperatures and show higher resistances against heavy-meals located in ore-material of this mining site. The objective of the work presented here was to establish the bioleaching of indium and zinc from sphalerite ore und low-temperature-conditions with bacteria enriched from mining effected sites, and to identify the naturally occurring bacterial community in these applications.

In the case of leaching, the main interesting fact is the extraction of important metals from ore-material. We focused on zinc and the socialiced strategic element indium. In this work we compared the results for leaching process at pH 2.6 and pH 1.6. Not only metal release was measured, also pH, ORP, iron content and biomass by cell enumeration were monitored.

The pH values of the approaches starting at pH 2.6 decreased to 2.4 for all tested cultures. In contrast, when using leaching medium with a pH of 1.6, this parameter increased up to 2.2. The redox potential was not affected by pH and increased during the time of leaching from 600 mV up to about 850 mV. In leaching solutions with pH 2.6 no ferrous iron was detectable after 12 days, whereas in approaches running at pH 1.6 it was consumed within the first 9 days. The time-dependent extractions for zinc and indium are shown in Fig. 1(a) and (b), respectively. In approaches starting at pH 2.6 the extraction of zinc from sphalerite ore proceeded nearly linear and ended up at 36 to 40%, whereas only 25 to 28% of indium were recovered. The leaching approaches at lower pH values were much more successful, since 70-77% zinc and 47-54% indium came into solution.

In previous studies, leaching tests at 30°C were performed. Here, in leaching-solutions with pH 2.6 extraction yields of 73% for zinc and 41% for indium were achieved after 34 days of leaching. At this moderate temperature, the advance of the lower pH 1.6 seems to be not that considerable, because just about 81% of zinc and 49% of indium were dissoluted from the ore material.

Next to these physico-chemical parameteres, the composition of the microbial diversity was checked, using the 16S rRNA fingerprint method T-RFLP (terminal restriction fragment length polymorphism) and 16S rRNA metagenome sequencing by Illumina. The evaluation of the results is still in progress.

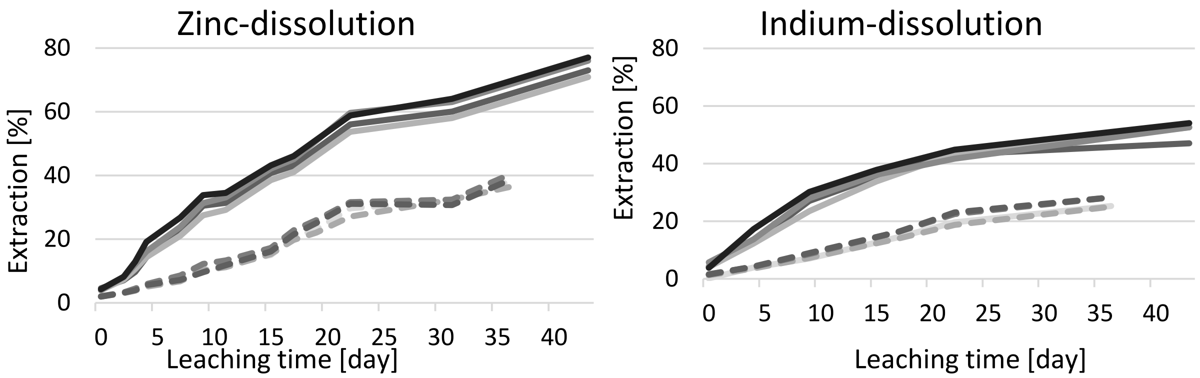

***Figure 1**: Dissolution of zinc (a) and indium (b) against time of leaching. The continous lines show results for applications with start pH 1.6 and dotted lines for start pH 2.6.*

In this work leaching applications in shaking flasks were performed at low temperatures. Thereby it was shown, that bioleaching at 11°C depends considerable on pH and results in higher metal dissolution, if pH of leaching solution is lower. This observation is very important for later applications inside of the mining field, where the temperature is as aforementioned low. Hence leaching should be as efficient as possible. The comparison to leaching approaches at 30°C points out, that the influence of pH under cold conditions is much higher compared to higher temperatures used in heap-leaching for example. Hence, for *in-situ* mining site in the underground the parameter pH becomes very important for successful leaching application.

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