Lecture 15

Bioleaching Of Zinc Sulfide Ores And Concentrates

Keywords: Zinc Bioleaching, Sphalerite, Zinc Concentrates

The leaching rate of zinc with mixed cultures of *Acidithiobacillus ferrooxidans* and *Acidithiobacillus thiooxidans* is higher than that of *Acidithiobacillus ferrooxidans* or *Acidithiobacillus thiooxidans* alone [87]. Moreover, the addition of an appropriate concentration of ferric iron to the leaching systems is beneficial to zinc dissolution. Too high Fe$^{3+}$ concentration reduces the rate of zinc dissolution due to the formation of jarosites. In addition, XRD, SEM and EDS analyses of the residues also indicate that elemental sulfur layers exist on the surface of sphalerite leached without bacteria or only with *Acidithiobacillus ferrooxidans*. These layers block the mineral surface from being attacked by the bacteria. The residues bioleached by *Acidithiobacillus thiooxidans*, however, show no sulphur existed.

The mechanism of accelerating the zinc dissolution rate through the mixed culture is given below: *Acidithiobacillus ferrooxidans* regenerate the oxidative ferric iron that is consumed in the leaching process and keep a high redox potential. The role of *Acidithiobacillus thiooxidans* is to oxidize elemental sulfur layers to sulfuric acid, which is beneficial to chemical leaching of the sphalerite:

\[
\begin{align*}
\text{ZnS} + \text{ZH}^+ &= \text{Zn}^{2+} + \text{ZH}_2\text{S} \\
2\text{H}_2\text{S} + \text{O}_2 &= 2\text{S}^0 + \text{H}_2\text{O} \\
2\text{S}^0 + 3\text{O}_2 + 2\text{H}_2\text{O} &= 2\text{H}_2\text{SO}_4 \\
\text{ZnS} + 2\text{Fe}^{3+} &= \text{Zn}^{2+} + 2\text{Fe}^{2+} + \text{S}
\end{align*}
\]

Mechanisms in the bioleaching of sphalerite in the presence of *Acidithiobacillus spp.* and a leaching model are illustrated in fig. 15.1.
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Zn\(S\) + 2\(Fe^{++}\) + \(O_2\) = \(Zn^{++}\) + \(S^0\) + \(H_2O\)

\(4Fe^{++} + O_2 + 4H^+ = 4Fe^{+++} + 2H_2O\)

\(ZnS + 2Fe^{+++} = Zn^{++} + S^0 + 2Fe^{++}\)

\(2S^0 + 3O_2 + 2H_2O = 2H_2SO_4\)

Acidithiobacillus

Chemical leaching

Bacterial leaching

Fig. 15.1: (A) Electrochemical and (B) Shrinking core models for sphalerite oxidation
Biooxidation of a fine-grained, complex zinc and gold-containing sulphide ore has been performed in a series of experiments at bench scale with 20 l leaching volume in a series of three continuously stirred reactors. A mixed culture of moderate thermophilic bacteria was used for bioleaching at 45°C and a mixed culture of extreme thermophilic archea were used for bioleaching at 65°C [88]. The leaching rates for zinc were in the range 80-87% with the moderate thermophilic bacteria and 96-98% with the extremely thermophilic microorganisms. It was found that, to obtain a high zinc recovery with a low degree of pyrite oxidation, a fine particle size was essential. Changes in retention time did not influence zinc solubilisation to any greater extent. Fig.15.2 shows the advantage of bioleaching of sphalerite using thermophilic bacteria in place of mesophiles.

![Graph showing bioleaching of sphalerite using mesophilic and thermophilic strains](image)

**Fig 15.2: Bioleaching of sphalerite using mesophilic and thermophilic strains**

Heap bioleaching of low grade zinc sulfide ores offers great promise. A HydroZinc\textsuperscript{TM} process was developed by Teck Cominco Metals Ltd, which incorporates heap bioleaching of zinc sulfide ores along with subsequent neutralization, solvent extraction and electrowinning. Column leaching tests as well as demonstration bioheap tests were carried out. About 82% zinc recovery after 740 days was attained [89].
A comprehensive modeling study of the above heap bioleach process using Heapsim modeling was also undertaken. The model took into consideration various sub-processes such as mineral and sulfur oxidation, ferric ion reduction, topological effects, particle size distribution, microbial growth, attachment and activity, as well as solution flow and heat balance. Zinc sulfide (as marmatite) and iron sulfide (as pyrite) were used in reaction kinetics and electrochemical models. Optimized parameters were

- **Heap height**: 6-8 m
- **Irrigation rate**: 10-15 Kg/m²/h
- **Side length**: 0.20 – 0.15 m
- **Acid**: 15 g/L

400 day simulation has projected an optimized scenario at 78% zinc extraction [90].

GeoBiotics, LLC has developed a proprietary heap bioleaching technology for the processing of sulphide base metal concentrates [91]. In this process, known as GEOCOAT®, thickened flotation concentrate is contacted during heap stacking with gravel-sized support rock, forming a thin adherent concentrate coating on the support rock particles. The stacked heap has an open structure and is highly permeable to the flows of solution and air. Acid solution, which contains acidophilic bacteria, is circulated through the heap to biooxidise and leach the contained metals. The heat produced by the exothermic oxidation reactions causes the internal temperature of the heap to rise. Heat is transferred to the percolating solution and to the air blown up through the heap. Rates of solution application and aeration can be varied to control the heap temperature and maintain it within the optimum range for bacterial activity. GeoBiotics and Kumba Resources have investigated the feasibility of the above process to the leaching and recovery of zinc from a low-grade sphalerite concentrate produced from accumulated flotation tailings at Kumba’s Rosh Pinah zinc mine in Namibia. To confirm that a GEOCOAT® heap to bioleach this concentrate would operate autothermally, a large engineering column test was conducted. The column was filled to a 6 m height with concentrate coated support rock. After acid stabilization the column was inoculated with an adapted mixed mesophilic bacterial culture. The temperature in the column was increased from ambient to a maximum of 49 °C. The solution
application rate and the aeration rate were adjusted to control the temperature and to prevent it from rising beyond the maximum tolerable by mesophiles. Final zinc dissolution after 90 days was 91% with a corresponding sulphide sulphur oxidation of 89%. Concentrations of in excess of 90 g/l Zn in the column effluent did not appear to inhibit the microbial oxidation. The operation of the large diameter column was successful in demonstrating that the GEOCOAT® process can be operated autothermally at mesophilic temperatures treating a low-grade sphalerite concentrate. Zinc dissolution in excess of 90% can be achieved in a leach time of 60 days, while results of small diameter column testing indicate zinc dissipations in excess of 95% in 60–100 days.

BioZinc™ process developed by BHP Billiton Ltd uses tank oxidation and leaching of zinc sulfides.

Yet another process has been developed for zinc production from zinc concentrates by integrating zinc bioleaching with zinc solvent extraction and electrowinning. The zinc bioleaching stage was developed from small scale continuous trials through to the construction and operation of a 1300L scale pilot plant. Using both a commercial zinc concentrate, and a mixed lead-zinc concentrate as feedstocks, zinc extraction of 95-99% were obtained, depending on the process conditions. The integration of zinc bioleaching with solvent extraction and electrowinning has significant advantages including a simplified flowsheet resulting in low capital costs, high zinc recoveries and the supply of the key reagent requirements (such as sulphuric acid and CO₂) for the bioleach. A fully integrated zinc pilot plant based on the integrated process was operated over a 12 month period, treating both the zinc concentrate and mixed lead-zinc concentrate feeds. Overall zinc recoveries of 96% (for the zinc concentrate) and 93-96% (mixed lead-zinc) were obtained, with routine production of SHG zinc cathode [92].
References


