COBALT AND ZINC EXTRACTION FROM SIKKIM COMPLEX SULPHIDE CONCENTRATE

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ABSTRACT

The lead concentrate produced from the complex sulphide deposit of Sikkim is not suitable for usual treatment processed like smelting due to high bismuth content. The present investigation has been carried out to study the amenability of the above concentrate towards leaching – both chemical and bioleaching. Bioleaching of the concentrate using *Thiobacillus ferrooxidans* in a 2 litre bioreactor resulted in about 39% extraction of both cobalt and zinc after 168 hours of leaching under the following conditions: pulp density 10%, pH 1.5, stirring speed 500 rpm, bacterial population $10^8$ cells/ml, temperature 35o C and air flow rate 200 cc/min For chemical leaching different routes were tried like oxidizing roasting followed by acid leaching, direct sulphuric acid leaching, ammonia pressure leaching and ferric chloride leaching. Addition of lignin sulphonate as surface-active agent during sulphuric acid leaching significantly increased the recoveries of cobalt and zinc. Increasing the leaching temperature did not have significant effect on the recoveries, whereas acid concentration showed significant effect. At 140o C, 5 kg/cm² oxygen partial pressure, 2.5 % (v/v) H₂SO₄ and 10% pulp density, 95% Co and 100% Zn could be extracted in 3 hours.

1. INTRODUCTION

The demand for cobalt in India is about 600 tons/year. Cobalt is mostly imported and partly produced from secondary sources. Essentially all of the world’s cobalt production originates as a by-product of copper and/or nickel whereas zinc is mainly produced from sphalerite concentrate by Roast-Leach-Electrowin (RLE) method. With the development of zinc production in India during last two decades, about 60% demand for zinc is currently being met by indigenous sources.

The stringent environmental restrictions imposed on the sulphide smelters and need to utilize small and complex deposits stimulated the development of alternative methods especially hydrometallurgical routes that avoid the production of sulphur dioxide, a pollutant. The conventional method for the dissolution of Ni-Co sulphides is either acid pressure leaching or oxidative ammonia leaching. For zinc sulphide concentrate various leaching agents have been tried and reported in the literature, but the most extensively studied one is the sulphuric acid pressure leaching. Forward and Veltman first suggested direct acid pressure leaching of sphalerite concentrate. After laboratory and pilot plant studies, a hydrometallurgical process based on pressure oxidation of zinc sulphide concentrate was first commercially developed by Sherritt Gordon, Fort Saskachewan, Canada.

Acidoophilic bacteria belonging to the genus *Thiobacillus* have been widely used for the leaching of sulphide minerals. Bioleaching of metals from sulphide minerals is being explored using bioreactors.

From a relatively small and complex sulphide ore deposit of about 1 million ton located in Sikkim, India, Sikkim Mining Corporation (SMC) is producing both bulk and individual concentrates of copper, zinc and lead. About 1000 tons of lead concentrate is lying with SMC unsold/untreated due to high bismuth content.

The main objective of the present investigation was to test amenability of the SMC lead concentrate towards different chemical leaching routes as well bioleaching using *T. ferrooxidans* for maximum cobalt and zinc extraction (with minimum iron) in the leach liquor.
2. EXPERIMENTAL

2.1 Concentrate

The lead concentrate used in the study was supplied by Sikkim Mining Corporation. The chemical composition of the concentrate is given in Table 1. The –150 μm particle size fraction was used for the investigation.

2.2 Pressure Reactor

Pressure leaching experiments were conducted in Parr 2 L autoclave with titanium liner and internal parts made of titanium. Temperature was controlled through a PID controller with digital read-out for temperature, pressure and agitation speed. For each run, 1000 ml aqueous solution of predetermined strength of leaching agent, 100 g concentrate and additives were charged into the vessel and the reactor closed properly. Prior to heating the autoclave, gas volume was purged with nitrogen three to four times to make the environment oxygen free during heating. Reactor was heated to the desired temperature and when the set temperature reached, oxygen was introduced and full agitation was placed.

2.3 Microorganism

*Thiobacillus ferrooxidans* used in this study was isolated from zinc tailings. The organism was grown in 9K medium and when more than 95% ferrous was oxidized, culture was harvested and preserved. The adapted culture was developed by transferring 5 ml aliquots, after 10 days from the previous set into the next set containing higher pulp density (upto 10%).

2.4 Bio-reactor

Batch studies of bioleaching were carried out in 2 litre capacity bioreactor having provision for stirring and aeration. Stirring was done with mechanical stirrer to which 4 perpendicular rods were attached. Air was supplied from a compressor through a sparger fixed at the bottom. Bioleaching experiments were carried out taking 1620 ml of ferrous free 9K medium and 180 ml of fully-grown inoculums.

3. RESULTS AND DISCUSSION

3.1 Bioleaching

Before conducting bioleaching studies in the bioreactor, shake flask experiments were carried out to study the influence of pulp density, pH and retention time. Detailed results are reported elsewhere10,11. During bioleaching in the bioreactor following conditions were maintained: bacterial population 10⁸ cells/ml, agitation speed 500 rpm, air flow rate 200 cc/min., pH 1.5 and temperature 35°C.

Figures 1 and 2 show the metal extraction achieved at 10% pulp density in the 2-litre bioreactor. After 126 hours of leaching, zinc and cobalt extraction was found to be 34.8% and 27.3% respectively (Fig.1). The acid consumption was 137.6 g H₂SO₄ / ton of concentrate. Keeping other conditions same, leaching

<p>| Table 1 |
|-------------------|---|---|---|---|---|---|---|
| <strong>CHEMICAL COMPOSITION OF SIKKIM COMPLEX SULPHIDE (LEAD CONCENTRATE).</strong> |</p>
<table>
<thead>
<tr>
<th>Zn</th>
<th>Co</th>
<th>Cu</th>
<th>Pb</th>
<th>Fe</th>
<th>S</th>
<th>Bi</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.49%</td>
<td>0.82%</td>
<td>0.9%</td>
<td>18%</td>
<td>25.5%</td>
<td>23.1%</td>
<td>0.56%</td>
<td>0.11%</td>
</tr>
</tbody>
</table>

Fig. 1: Extraction of cobalt and zinc in 2 litre bioreactor [Time 126 hr, pH 1.5, air flow rate 200 cc/min, agitation 500 rpm, 35°C, bacterial population 10⁸ cells/ml]
time was increased in the second experiment to 168 hours and the extraction values for zinc and cobalt were 39.4 and 38.7% respectively after 168 hours (Fig.2). Although zinc extraction was marginal, cobalt extraction increased significantly with increasing time. The percentage of zinc and cobalt obtained in bioreactor leaching is much higher than that obtained with shake flasks experiments11. It is known that carbon dioxide and oxygen are needed for actively metabolising T. ferrooxidans, which is an autotrophic microorganism. Due to heterogeneous nature of the system, thorough mixing of mineral, nutrient and microorganisms is essential. The above conditions are fulfilled in the bioreactor but not in shake flask, hence bioreactor resulted in increased recovery of metals.

3.2 Chemical leaching

Different leaching media were used in order to test the amenability of the concentrate towards leaching of cobalt and zinc values. Preliminary tests were conducted with roasting following by dilute acid leaching. Roasting was done at 200°C for 2 to 6 hours duration. Roasted mass was leached in 2% (v/v) H₂SO₄ at 95°C for 2 hour. But extraction of zinc and cobalt was very low - only 2% and 10% respectively.

The next sets of experiments were conducted keeping in view the usual leaching agents used for base metal sulphides. The conditions of leaching and corresponding extraction values of cobalt and zinc after 3 hours of leaching are given in Table 2.

From the results shown in Table 2 it is evident that sulphuric acid pressure leaching results in better cobalt recovery. Besides good metal recoveries iron contamination of the leach liquor is comparatively less, which is desirable for downstream processing.

During leaching of sulphide materials in acidic media, elemental sulphur forms as a by-product. Since sulphur melts at 120°C, some suitable surface-active agents to be used if leaching is done at temperature >120°C in order to prevent molten sulphur from wetting the unreacted sulphide particles. In the present investigation lignin sulphonate was used as surface-active agent.

Figure 3 shows the leaching results at two different temperatures 140°C and 155°C using 6g/l lignin sulphonate, 1.5% (v/v) H₂SO₄ and 5 kg/cm² oxygen partial pressure. At 140°C, cobalt recovery after 3 hour is 73% as compared to 23% without lignin sulphonate (Table 2). The higher temperature enhances the initial leaching rate but final cobalt recovery is same. Zinc recovery rate increases marginally with temperature. But temperature has a pronounced effect on iron precipitation. Final concentration of Fe in leach liquor at 140°C is 1.1 g/l whereas at 155°C it is 0.3 g/l, which is beneficial from the point of view of downstream processing.
biological leaching. Bioleaching of the concentrate at 10% pulp density resulted in 39% extraction of cobalt and zinc after 168 hours of leaching. Low temperature roasting followed by sulphuric acid leaching did not give significant recovery of cobalt and zinc. Sulphuric acid pressure leaching at 140°C resulted in 23% Co and 47% Zn recovery. When 6 g/l lignin sulphonate was used as a surface-active agent to disperse molten sulphur from wetting the unreacted particles, both cobalt and zinc recoveries were observed to increase. Increasing the temperature from 140°C to 155°C did not improve extraction values. Increasing sulphuric acid concentration was beneficial for the recovery of cobalt and zinc. With 2.5% (v/v) H₂SO₄, 140°C, 6 g/l lignin sulphonate and 5 kg/cm² oxygen partial pressure, 95% Co and 100% Zn values could be leached in 3 hours.

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REFERENCES


Figure 4 shows the effect of acid concentration on metal recovery at 140°C and 5 kg/cm² oxygen partial pressure. It is observed that cobalt recovery increased from 73% (at 1.5% H₂SO₄) to 95% (at 2.5% H₂SO₄). Zinc recovery also increased from 73% to 100% with increase in acid concentration.

4. CONCLUSIONS

The lead concentrate produced from complex sulphide ores of SMC was tested for amenability to bioleaching as well as chemical leaching. Bioleaching of the concentrate at 10% pulp density resulted in 39% extraction of cobalt and zinc after 168 hours of leaching. Low temperature roasting followed by sulphuric acid leaching did not give significant recovery of cobalt and zinc. Sulphuric acid pressure leaching at 140°C resulted in 23% Co and 47% Zn recovery. When 6 g/l lignin sulphonate was used as a surface-active agent to disperse molten sulphur from wetting the unreacted particles, both cobalt and zinc recoveries were observed to increase. Increasing the temperature from 140°C to 155°C did not improve extraction values. Increasing sulphuric acid concentration was beneficial for the recovery of cobalt and zinc. With 2.5% (v/v) H₂SO₄, 140°C, 6 g/l lignin sulphonate and 5 kg/cm² oxygen partial pressure, 95% Co and 100% Zn values could be leached in 3 hours.


