

Bioleaching and chemical leaching as an integrated process in the zinc industry

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Abstract

This work sought to integrate bioleaching and chemical leaching as a cost-effective process to treat zinc sulphides. The continuous bioleaching of a sphalerite concentrate, assaying 51.4% Zn, 1.9% Pb, 31.8% S and 9.0% Fe with mesophile iron and sulphur-oxidizing bacteria followed by chemical leaching of the bioleaching residue were assessed. In the bioleaching step, the first reactor was used to produce Fe(III) concentrations as high as 20 g/L. This solution was fed to the subsequent bioleaching reactors to oxidize sphalerite. It was possible to achieve 30% zinc extraction for 70 h residence time. In chemical leaching experiments, carried out with the residue of the bioleaching step, the effects Fe_{total} and acidity on zinc extraction were studied. It was noticed that Fe(III) concentrations over 12 g/L did not affect zinc recoveries. Furthermore, the higher the acidity, the larger the zinc recovery, for experiments carried out up to 181 g/L sulphuric acid. The results have demonstrated that it is possible to devise a new process capable of achieving 96% zinc extraction, similarly to the conventional roasting–leaching–electrolysis process.

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1. Introduction

Primary zinc production can be carried out by basically two different routes: (i) the hydrometallurgical process proposed in 1916 and (ii) the imperial smelting process first introduced in Swansea (UK) in the 1960s. The hydrometallurgical process accounts for some 85% of the primary zinc production. Conversely, the imperial smelting process currently represents less than 15% of the world's zinc production and has been progressively abandoned. Other technologies include zinc pressure leaching (Cominco Trail, Flin Flon and Kidd Creek), atmospheric direct leaching (Outokumpu Kokkola and Onsan Korea Zinc), the integrated sulphide–silicate process (Votorantim Zinc) and

the solvent extraction process (Skorpion Zinc) (Souza, 2005).

The traditional hydrometallurgical production of zinc from its sulphides comprises roasting, leaching and electrolysis (Feneau, 2002), namely the RLE process. This process was devised to treat zinc sulphide concentrates and basically includes a zinc sulphide roasting step to produce ZnO and sulphur dioxide. The calcine (ZnO) is sent to leaching followed by the purification and electrolysis steps where special high-grade (SHG) zinc is produced (Fig. 1).

As far as alternative technologies are concerned, two similar routes have been proposed in the 1970s to leach zinc sulphides: (i) *Direct Atmospheric Leaching* (Svens et al., 2003) in which zinc sulphide concentrates are leached directly with a ferric iron solution (produced during the leaching step of the RLE process); and (ii) *Pressure Leaching* that adopts a similar approach except that leaching is carried out in autoclaves (14–15 atm oxygen pressure).

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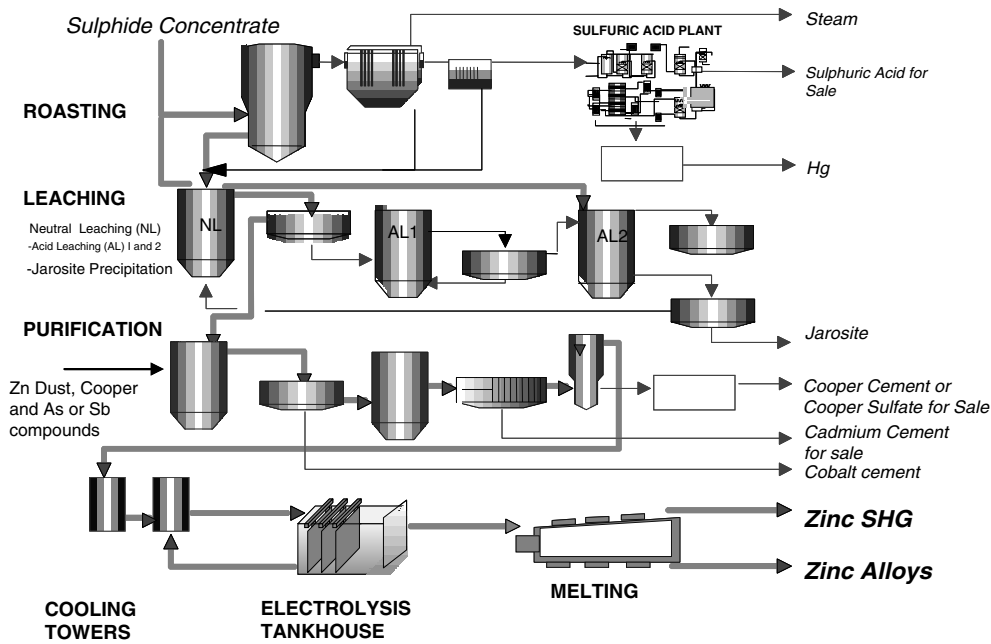
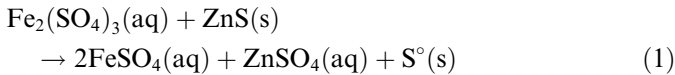


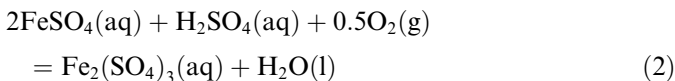
Fig. 1. Process flow sheet for zinc production by the roasting–leaching–electrolysis (RLE) route.

The high oxygen pressure achieved in the latter enables fast concentrate dissolution: 90 min is the standard residence time. Conversely, the direct atmospheric leaching process requires around 24 h for leaching and therefore larger reactors are required as compared to pressure leaching plants (Svens et al., 2003).

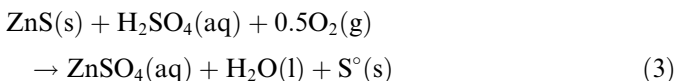
ZnS leaching by Fe(III) can be represented as follows:



Gaseous oxygen (93–98%) oxidizes the ferrous iron produced by Eq. (1) to Fe(III):



The overall leaching reaction is



The economics of these new processes is determined mainly by the oxygen consumption, a relatively expensive raw material. Furthermore, the elemental sulphur produced during ZnS oxidation by Fe(III) is not easily commercialised due to its usual high impurities content. Notwithstanding, capital costs are lower and sulphur dioxide is not produced in both processes. As a result, the latter are considered more environmentally friendly as compared to the RLE process.

Bioleaching can also be utilized to oxidize zinc sulphides (Boon et al., 1998; Brierley and Brierley, 2001). Although slower than chemical leaching, bioleaching of ZnS does not require gaseous oxygen since Fe(II) oxidation is carried

out by the microorganisms. In this case, air is required for bacterial respiration. A mixed process – bioleaching and chemical leaching – would therefore result in the reduction of the overall oxygen consumption while circumventing the high residence times observed in the complete bioleaching of zinc sulphides. This approach is currently been applied at the Sao Bento gold mine (Brazil) (Carmo et al., 2001) to reduce oxygen requirements in the pressure oxidation of refractory gold ores. The present work sought to apply this approach to leach zinc sulphides so that a new contribution to the technological development in the zinc industry is proposed. This was achieved by the application of aerobic acidophilic bacteria that oxidises ferrous iron and also reduces the production of elemental sulphur, since the sulphide ion is directly oxidized to sulphate. The first step comprised the partial bioleaching of concentrate followed by chemical leaching of the bioleaching residue.

2. Experimental

2.1. Bioleaching experiments

Continuous bioleaching experiments were carried out in a series of three bioreactors (R2, R3 and R4), the first one with a 20 L volume and the following two with a capacity of 12 L each (Fig. 2). This system was fed by (i) a pulp formed by the ZnS concentrate and sulphuric acid and (ii) a biologically produced ferric iron solution containing mesophile–acidophilic bacteria (Fe(II) biooxidation reactor, R1). As shown in Fig. 2, a 20 g/L a ferrous sulphate solution was pumped (3 ± 0.2 mL/min) to reactor R1 and the produced ferric iron solution was fed to reactor R2 by gravity where it joined with the zinc sulphide slurry

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