Hydrometallurgy 134–135 (2013) 144–149

Contents lists available at SciVerse ScienceDirect

Hydrometallurgy

journal homepage: www.elsevier.com/locate/hydromet

Column leaching of nickel laterite agglomerates: Effect of feed size

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ARTICLE INFO

Article history:
Received 13 September 2012
Received in revised form 5 February 2013
Accepted 7 February 2013
Available online 13 February 2013

Keywords:
Nickel laterite
Column leaching
Agglomerates
Particle size
Leaching kinetics

ABSTRACT

Heap leaching is a promising, less costly, alternative technology for processing low grade nickel (Ni) laterite ores compared with traditional, energy intensive processes (e.g. autoclave/tank leaching). However, significant technical challenges remain with Ni laterite heap leaching, preventing its general adoption. This paper presents some highlights of laboratory column leaching studies undertaken to characterise, evaluate and optimise sulphuric acid leaching behaviour of Ni laterite agglomerates. The main focus of the paper is to assess the effect of the initial feed ore particle size to the agglomeration stage on the leaching behaviour of the resulting agglomerates. This type of investigation provides basic but valuable information regarding Ni laterite agglomerate robustness and leaching performance under industrially-relevant, continuous acid irrigation conditions. In particular, Ni, cobalt (Co) and other key metals' (e.g. Fe, Mg, Al and Mn) extraction rates, acid consumption and bed slump were determined at a given acid percolation rate as a function of time >100 days. The findings show that the particle size of the agglomerate feed ore has a significant impact on the subsequent column leaching performance. Ni and Co recoveries of 90% and 80%, respectively, were achieved over 100 days for −38 μm size feed, 5–40 mm agglomerates, but these decreased by 10% for the agglomerates made from coarser feed particles (i.e., 2–15 mm). Potential implications of the findings for devising strategies for improved Ni laterite plant heap leach operations are discussed.

1. Introduction

The majority (e.g. 70%) of the world's nickel (Ni) resources occur as laterite ores which are exceptionally complex, lower grade (<1.5% Ni) and expensive to treat using conventional smelting and hydrometallurgical tank leaching methods. Typical capex values for High Pressure Acid Leach (HPAL) and Atmospheric Tank Leaching (ATL) are approximately three and two times that of heap leaching respectively (Wedderburn, 2009). Heap leaching is a promising, less costly, alternative technology for processing low grade nickel laterite ores. However, significant geotechnical and hydrometallurgical challenges persist with Ni laterite heap leaching, preventing its adoption. This paper presents recent laboratory column leaching studies undertaken to characterise and evaluate the sulphuric acid leaching behaviour of Ni laterite agglomerates. The work focussed on the effect of the initial particle size of the feed ore to the agglomeration stage on the leaching behaviour of the resulting agglomerates. Emphases are laid on establishing the initial leaching behaviour and analysis of performance as a major complementary exercise to our recent studies of Ni laterite agglomerates (Xu et al., 2012). A description of the effect of process variables on the drum agglomeration kinetic behaviour of this same nickel laterite ore has been reported by Nosrati et al. (2012). Robertson and van Staden (2009) have reported the steps involved in determining the amenability of ores to heap leaching. These involve bottle roll tests to determine the effects of mineralogy, crush size, acid consumption etc., followed by leaching behaviour testing in small (1 m) columns, then pilot columns and finally test heaps. This paper therefore represents the next stage of the overall process assessing and establishing the robustness of the agglomerates and reports how the effect of the initial particle size of the agglomerate feed material influences its long term leaching characteristics.

2. Previous studies

Research into heap leaching of nickel laterites began at the National Technical University of Athens in the early 1990s (Stamboliadis et al., 2004) involving crushing the ore to <10 mm, pelletising and heap leaching by 2 N sulphuric acid. Column leaching was used to simulate the heap leaching process. According to work conducted at the National Technical University of Athens, column reactors have been proven to be excellent simulators of heaps of similar height, as shown by the long

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http://dx.doi.org/10.1016/j.hydromet.2013.02.001

history of industrial operation of this technique in copper, gold and uranium mines (Stamboliadis et al., 2004). Leaching experiments are typically conducted in columns of 100 mm diameter and 1 m in height. Before loading, the ore is pelletised to give a permeable bed and allow percolation of the leach solution through the column. Leach solution volume/ore weight ratio of 0.8 L/kg and a percolation rate of 45.8 L/h.m^2 have been used as an example. According to Kyle (2010), these laterites were very amenable to heap leaching extracting up to 80% of the nickel and 60% of the cobalt at a minimal acid consumption of about 120 kg/t. In fact, heap leaching was originally thought to be only applicable to certain laterite ores such as the Greek laterites or highly saprolitic ores. The process is now being investigated for limonitic ores as well using the process of agglomeration with sulphuric acid as a binder to improve the permeability of the ores (Kyle, 2010).

Elliot et al. (2009) tested the leaching response of 50 arid-region nickel laterite ores from several deposits in Western Australia in 150 mm diameter columns after they had been agglomerated using 20 kg sulphuric acid/t ore in a rotating drum. Typical bed heights were 1 m and were irrigated with a 200 g/L sulphuric acid solution at 10 L/h.m^2 without recycle. Leach solutions were sampled daily and the solution parameters including selected elemental concentrations and acid consumption were measured. The height (slumping) of the ore bed was recorded periodically. Leach times were typically 120–150 days. The wide variety of nickel laterite ores tested resulted in a wide variety of nickel and cobalt extractions (~10–98%) as expected.

Watling et al. (2010) investigated the leaching characteristics of a particularly refractory Ni laterite ore from the Yilgarn province of Western Australia. The dominant Ni-bearing mineral phase was goethite, containing almost 80% of the Ni in the sample, with sub-dominant chromite (12%) and minor chlorite, smectite and serpentine. This sample contained ~45% goethite, 8% chromite, 25% quartz with ~8% of both serpentine and chlorite. The goethite present in this ore was relatively densely packed and thus offered reduced surface area for Ni extraction. A recent paper relating the ore mineralogy to processing Ni laterites under heap leaching conditions and published by Watling et al. (2011) provides additional information.

The paper by Elliot et al. (2009) formed the basis for the column leach testing reported herein. The sample selected was one of a number being studied in a larger CSIRO Minerals Down Under (MDU) supported nickel laterite beneficiation research projects. It is a typical Western Australian arid nickel laterite sample designated "siliceous goethitic". The run-of-mine ore sample was agglomerated using sulphuric acid prior to loading into the column. The main objective of the present work was to use column leaching tests to characterise and evaluate some aspects of the sulphuric acid leaching behaviour of a sample of agglomerates prepared from a characterised nickel laterite ore (siliceous goethitic). The main focus of the paper is the effect of the initial particle size of the feed to the agglomeration stage on the leaching behaviour of the resulting agglomerates.

Details of the method of preparation of the agglomerates used in the current leaching test have been reported by Nosrati et al. (2012). These authors investigated the effects of binder type/composition and dosage, drum speed, temperature and batch time on drum agglomeration behaviour of a siliceous goethitic Ni laterite ore. The starting material for the paper by Nosrati et al. (2012) was all passing 2 mm. The starting material for the current study was the same ore, but crushed to all passing 15 mm, 2 mm, 38 μm and a 60:40 blend of <15 mm and <38 μm materials.

3. Material examined

A sample of low grade Ni laterite ore (~1 wt.% Ni) from Western Australia, characterised as siliceous goethite (SG), was used in this study. Quantitative, powder X-ray diffraction and QEMSCAN analyses showed complex mineral associations where the hydrophilic quartz, goethite, nontronite and Mg-bearing silicates (e.g., serpentines, smectites) comprised the dominant minerals, with hematite, asbolane and kaolinite as the minor mineral phases (Table 1). Detailed mineralogy of this ore has been provided in a recently completed study accepted for publication (Swierczek et al., 2012). Furthermore, Ni and cobalt (Co) mineralizations were broadly disseminated in goethite, layered silicates (i.e., serpentines, smectites) and hydrous Ni-silicates, whilst a significant proportion of the oxides and layered silicates contained a small but noticeable amount of Ni. The "as received" ore (ROM) contained 12 wt.% moisture with particle size <15 mm (80% passing 2.4 mm, 50% passing 0.6 mm, and 20% passing 38 μm). Finer feed (<2 mm) ore was obtained by crushing the <15 mm ROM ore after semidrying and passing the product through a 2 mm sieve (28% passing 0.6 mm, 26% passing 38 μm). Stirred mill material was generated by grinding batches of the <2 mm laterite in a 1.7 L Netzsch mill at a pulp density of 40% solids by weight using a media charge of 50% of 3 mm grinding beads. This produced a product with 80% passing 38 μm. The <38 μm Ni laterite material was produced by wet sieving a stirred-mill product through a 38 μm sieve, bone-drying at a temperature of 50 °C for 72 h and then dry-brushing through a 2 mm sieve. The Ni grade was slightly increased (Table 2) compared to <38 μm Ni laterite feed due to the rejection of the >38 μm materials which contained less Ni.

4. Procedure

4.1. Preparation of agglomerates

Agglomeration tests were conducted in a batch, laboratory scale, 316 stainless steel agglomerator (0.3 m in diameter and 0.2 m in length) at a fixed rotational speed of 60 rpm corresponding to 77% critical speed. To investigate the effect of feed particle size on column leaching behaviour of N laterite agglomerates, four types of SG feed ore material (5 kg, air equilibrated weight): (i) <15 mm ROM, (ii) <2 mm crushed from the <15 mm material, (iii) <38 μm stirred mill product and (iv) a <15 mm/<38 μm blend (60/40 by weight) were used to produce agglomerates. Dilute sulphuric acid solution (200 g/L) was used as a binder. The use of more concentrated sulphuric acid is not appropriate for the current process of agglomeration. Where concentrated (e.g. 98%) sulphuric acid is employed in industrial applications, water is added for dilution, hence the use of 200 g/L sulphuric acid is consistent with the industry norm. Ore feed and binder charges were: 1250 g ore and 25 wt.%, 23 wt.%, or 33 wt.% charges of binder for <15 mm ROM, <2 mm crushed, <38 μm stirred mill product and <15 mm/<38 μm blend, respectively, per batch experimental run. Before charging, the ore and binder were first pre-mixed over 2 min and the mixture was transferred into the drum and agglomeration commenced. The different amounts of binder content used in this work were pre-determined as the optimum required to generate agglomerates in the size range 5–40 mm at 14 min of agglomeration time. The differences in binder content required are due to the variation in the initial moisture content, ore mineralogy and size/surface areas of the feed particles. By changing the binder dosage, the agglomeration time can be reduced to <3 min, however the optimum conditions were chosen for laboratory research to cover a wide range of feed

Table 1
Mineralogical composition of ROM SG Ni laterite ore.

Mineral phase	Mass %
Quartz	36.06
Kaolinite	0.21
Mg-bearing silicates	8.71
Nontronite (smectite group)	18.77
Goethite	27.43
Hematite	2.81
Asbolane	0.40
Other	5.64