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Atmospheric acid leaching of nickel laterites review
Part I. Sulphuric acid technologies

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Abstract

This review examines the atmospheric leaching (AL) of nickel laterite ores with sulphuric acid, specifically the limonite, smectite (clay) and saprolite fractions. The kinetics and mechanism of leaching of the key minerals are reviewed together with methods for enhancing nickel recovery. Existing and developing AL processes for extracting nickel and cobalt from these ores are then considered with comparison to high pressure acid leaching (HPAL) technology. This review also provides an overview of the emerging hybrid HPAL/AL and heap leaching technologies.

Keywords: Atmospheric leaching; High pressure acid leaching; Sulphuric acid; Nickel laterite; Nickel processing

1. Introduction

Today, there is an increasing focus on the processing of the huge reserves of nickel-rich laterite ores due to declining global reserves of nickel sulphides. In 2003 it was estimated that 72% of the world land-based nickel resources were contained in nickel laterites, although these only accounted for 42% of the world nickel production (Sudol 2005). Demand for nickel had risen from under 200 ktpa in 1950, to over 1200 ktpa in 2003 and was growing at an average of 4% pa. The development of new technologies, including high pressure acid leaching (HPAL) and atmospheric (acid) leaching (AL) processes make the processing of such ores economically feasible. Canterford (1972), Anthony and Flett (1997) and Whittington and Muir (2000) reviewed the minerals and the processes that can be used to extract nickel with the focus on HPAL in recent articles. Taylor (1997) briefly summarised AL processes and the chemistry relevant to low-temperature acid leaching to foresee where future processes might be developed. Several other reviews relating to both pyrometallurgical and hydrometallurgical processes for nickel laterites are referenced in an excellent overview on the status of nickel laterites by Dalvi et al. (2004).

The chemistry of the HPAL process has been reviewed by Whittington and Muir (2000). Briefly, blended ore is slurried and heated to 250–255 °C in a titanium-clad autoclave via the injection of steam and sulphuric acid and the nickel and cobalt are extracted into the acidic solution, together with iron and aluminium. At these high temperatures, the iron and aluminium hydrolyse and precipitate as hematite and a range of mixed alunite/jarosite phases, depending on the leaching conditions. This hydrolysis

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generates acid and reduces the overall acid consumption of the HPAL process but leaves about 50–60 g/L free acid in the leach solution. The leach slurry is ‘flashed’ from the autoclave, the solids are separated from the liquor by counter current decantation (CCD), the liquor neutralised to remove iron(III), aluminium and chromium(III) and the soluble nickel and cobalt are subsequently processed.

Atmospheric leaching (AL) at lower temperature and in open vessels avoids the need for expensive HPAL autoclaves. However, two key issues are the kinetics of nickel extraction and the ease with which the liquor can be processed subsequently. Specifically, the leach liquor from AL is likely to contain significant concentrations of soluble iron and aluminium and methods must be found to selectively reject these metals from solution or selectively extract nickel and cobalt (Willis, 2007).

The case for AL versus HPAL has been debated for many years and gives rise to a substantial list of relative strengths and weaknesses as summarised in Table 1. Reid and Barnett (2002) concluded that for AL to be competitive with HPAL, it would have to “give good recoveries, allow acceptable acid consumption and produce low residual iron in solution”. Griffin et al. (2002) considered the choice between AL and HPAL to be an economic one relating to acid supply cost, the mineralogy of the ore body and trade offs in recovery versus lower cost plants. Neudorf (2007) concluded that AL in itself may not represent a quantum process development shift and other factors, particularly those related to infrastructure, may require significant improvement. It is clear from Table 1 that a range of considerations must be examined when determining if AL is a viable processing option.

This review first considers the mineralogy and reactivity of nickel laterites including selective leaching of various ore types (*viz.* limonite, smectite, saprolite). It

Table 1
Advantages and disadvantages of atmospheric leaching (stirred tank or heap) as compared to pressure acid leaching

Expected advantages	Refs.	Expected disadvantages	Refs.
Lower CAPEX	b, d, e, g, h	Higher acid consumption (to obtain acceptable nickel recoveries)	a, b, c, d, e, g, h
Conventional equipment technology	c, e, f, h	Residue more voluminous (from tank leaching)	h
Cheaper (less exotic) materials of construction	b, h	More magnesium in the waste liquor compared to limonite HPAL	g, h
Lower maintenance costs	c, d, e, h	May consume more limestone	h
Higher plant availability	c, h	No significant improvement in OPEX (depending upon how second generation HPAL plants perform)	h
Faster ramp-up	h	Cannot be applied to all ore bodies (mineralogy dependent); less effective for treating limonites	a, e, f, h
Easier start-ups and shut-downs	h	Not yet commercially proven	h
Not prone to “catastrophic” shut-downs	h	Slower extraction kinetics and hence longer residence times	c, d, h
Less specialized workforce for construction, operations and maintenance	h	Produces highly contaminated liquor with significantly lower nickel to iron ratio; downstream processing more challenging (*e.g.* solid–liquid separation)	b, d, e
Many suppliers of major, “common” equipment	h	Lower nickel and cobalt extractions (esp. from neutralising ores)	c, d, f
Better acid utilisation	h	Presence of more jarosite in tailings potentially an environmental problem	c, f, g
Lower energy consumption, leaching autogenous	b, h	Longer residence times	c, d, f, g
Simpler energy system	h	CAPEX still relatively high	e
Simpler process control	h	Requires correct blending of limonite and saprolite	e
Easier recycle of process water	h	Heap permeability critical	e
Heap leaching far less complex than HPAL or AL (*e.g.* no CCD, no tailings disposal)	e, h	Sulphate losses due to jarosite formation	f, g
May lower cut-off grades	h		
May be better suited to remote, undeveloped locations	h		
Process both limonite and saprolite	e, f, h		
Lesser scale and corrosion problems	a, b		
Economic if cheap sulphuric acid available	a		
Use of sea water to provide sodium for iron rejection	c, e		
Smaller operations allow for substantially lower investment with heap leaching	i		

a. Canterford (1979); b. Chander (1982); c. Reid and Barnett (2002); d. Griffin et al. (2002); e. Wedderburn (2005); f. Neudorf and Huggins (2006); g. Smit and Steyl (2006); h. Neudorf (2007); i. Santos de Pontes Pereira and De Araújo Gobbo (2007).