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Challenges in processing nickel laterite ores by flotation

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The challenges in processing nickel laterite ores using flotation process were comprehensively reviewed. Literature shows that flotation has not been successful to recover nickel from laterite ores. Nickel in laterite ores is often finely disseminated in various minerals in very fine size. Therefore, fine grinding can be useful to liberate nickel-containing particles. However, particles resulted from fine grinding are often very fine, and recovery of such particles is low in the conventional flotation cells. It has been suggested that using reactor–separator cells with more probability of particle–bubble attachment can be useful to recover fine particles. Therefore, these types of cells (or similar) should be tested in processing laterite ores. In addition, increasing particle size often results in enhancing the particle–bubble interaction in flotation. Selective flocculation of fine particles could be therefore the key parameter to improve the flotation performance of laterite ores. Flocculation of these type of ores needs to be thoroughly investigated.

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1. Introduction

Nickel is an important metal with the total global consumption of about 2 million tons per year which has grown rapidly since the 1940s (Fig. 1) (Mackey, 2011). Nickel is sourced from two different types of ores, sulphide and laterite. The majority of the world's nickel resources occur as laterite ores which are complex, low grade, and expensive to treat using conventional smelting and high-temperature and/or high-pressure autoclave methods (Xu et al., 2013). While about 70% of the nickel resources are contained in laterites, only 40% of the world's nickel production comes from these ores. The main areas with the large nickel laterite resources in the world are New Caledonia, Australia, Indonesia, South America (Colombia and Brazil), The Philippines, India, and Russia (Einhorn, 2015). It should be noted that these days nickel laterites are more attractive for production of nickel as the amount of high-grade nickel sulphide ores has been diminished (Janwong, 2012). Therefore more economic processes to recover nickel from these resources should be developed.

Researchers have tried to improve nickel laterite flotation recovery by using a number of feed preparation techniques. A summary of the nickel grade upgrade using flotation reported in the literature is presented in Table 1. It can be seen that only minor nickel upgrades have been reported. Thus, the challenge of processing nickel laterite ores still exists. In fact, no physical separation technique (including flotation) has been able to dramatically upgrade nickel in laterite ores (Quast et al., 2015a). The only isolated case with an acceptable nickel upgrading is the result by Denysschen and Wagner (2009). They used dense medium separation ahead of flotation of a low-grade nickel ore at Tati Nickel Mine in Botswana. However, this work is not included in Table 1 as

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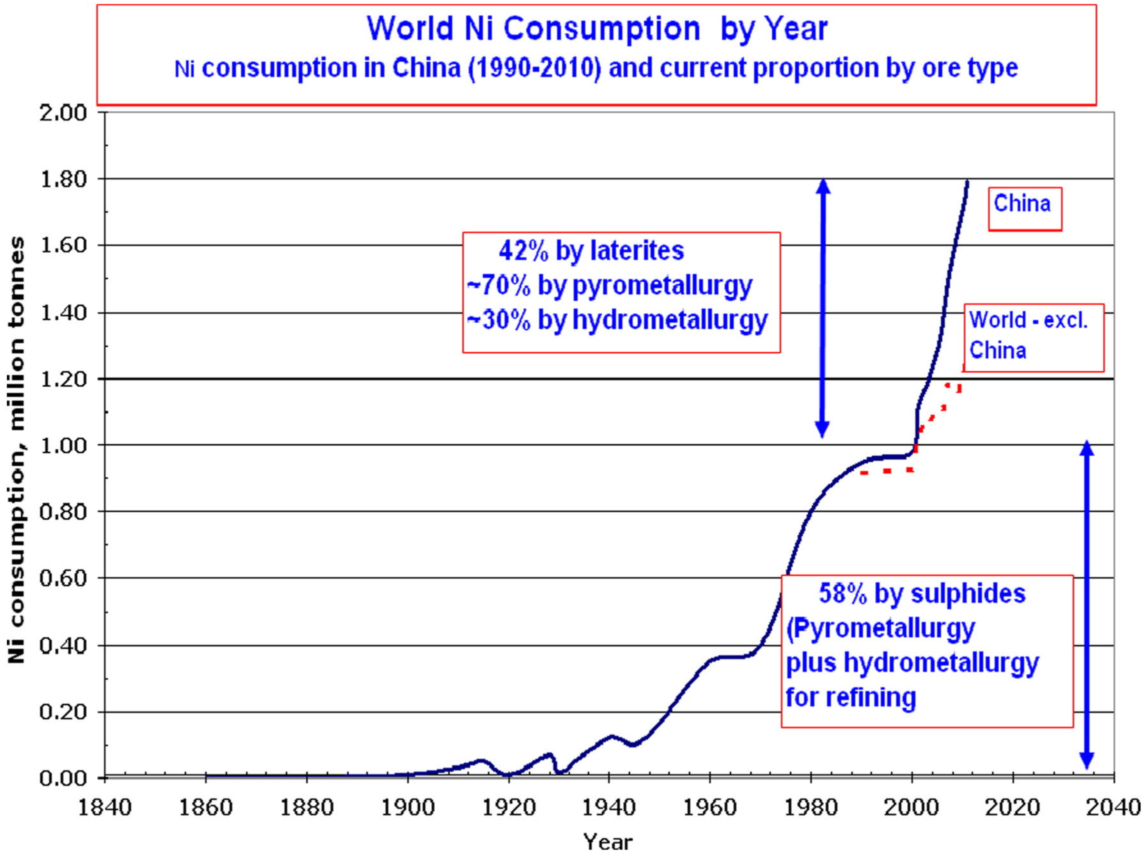

Fig. 1. World nickel consumption (Mackey, 2011).

the ore they used was indeed a nickel sulphide, but the authors had classified it as lateritic probably because of its low grade.

It should be added that segregation of laterite ores prior the flotation process has shown some improvement in upgrading nickel. The segregation process relies on the addition of calcium chloride or sodium chloride and carbon allowing the formation of nickel and iron chlorides at temperatures between 900 and 1150 °C. Iwasaki et al., (1961) and Nagano et al., (1970) have reported nickel concentrate with 22–37% and 5–7% nickel using saprolitic and goethite ores, respectively. Harris et al. (2013) have also applied segregation to nickel lateritic ores before flotation and obtained an average nickel grade of 4–5% (Table 1).

Reverse flotation has been also used for an Indonesian iron-rich laterite ore to float siliceous minerals. Calcine laterite product was obtained from reduction at 900 °C by transforming limonite–goethite to magnetite. The reverse flotations was used to separate iron from nickel mineral using amine thioacetate, as collector (Purwanto et al., 2011). One stage rougher reverse flotation resulted in 0.5% nickel grades (at 33% recovery) which is not commercially acceptable.

Quast et al. (2015a) have reviewed the application of various techniques of pre-concentration of nickel laterite ores prior to hydrometallurgical or pyrometallurgical process. They concluded that the complex mineralogy of nickel laterite ores makes it difficult

Table 1
A summary of the reported data on upgrade nickel in laterite flotation (partly adapted from Quast et al., 2015c).

Ore source	Conditions	Head grade	Ni grade @ recovery	Ref.
Brazil	Synthesised 2,3 octanedione dioxim as collector	1.2%	1.4% at 63%	Teoh et al., 1982
New Caledonia	Micro-flotation of 53–74 μm fraction using a variety of reagents. Best selectivity by using cetyl trimethyl ammonium bromide (CTAB) or sodium oleate		No or minor upgrading	Onodera et al., 1987
India	Anionic collectors plus sodium silicate	0.6%	1.6% at 60%	Rao and Charan, 1989
India	Cationic collectors and starch to recover Ni from a cyclone overflow of 20 μm	0.8%	1.3% at 86%	Rao and Charan, 1990
India	Pre-concentration by rejection of coarse fraction with low Ni amount, followed by hydrocyclone and attrition scrubbing. Flotation of the cyclone underflow using petroleum sulphonate, sodium silicate and pine oil	0.5%	1% at 82%	Rao et al., 1995
India	Sodium lauryl methylamino acetic acid and sodium salt of modified carboxylic acid	0.5%	1% at 70–80%	Rao and Sastri, 1996
India	Various reagents including hydroxy quinoline, dimethyl glyoxime, nitroso pyrazolone, 2,2 bipyridal, triethonolamine and sodium oleate	0.5%	Slightly upgrade at 40–60% recovery	Mohanty et al., 2000
Ivory Coast	Segregation of nickel laterite ores followed by flotation using sodium silicate as dispersant	1.2%	6–8% at 35–45%	Harris et al., 2013
Australia	A number of feed preparation techniques before flotation	1%	1.4% at 43%	Quast et al., 2015c

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