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Extraction of nickel by microbial reduction of lateritic chromite overburden of Sukinda, India

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HIGHLIGHTS

- ▶ Fe^{3+} in the goethite of COB was reduced by *Acidithiobacillus ferrooxidans*.
- ▶ Reduction of Fe^{3+} in goethite favoured nickel extraction from COB.
- ▶ Reductive microbial approach explored a new avenue to extract nickel from COB.

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ABSTRACT

Microbial extraction of nickel from lateritic chromite overburden (COB), Sukinda by *Acidithiobacillus ferrooxidans* has been investigated in this work. In anoxic environment, *A. ferrooxidans* reduced the ferric iron in goethite [Fe(O)OH] mineral of COB by using elemental sulphur as electron donor. Nickel embedded in the complex goethite matrix of COB was successfully recovered by cumulative action of sulphuric acid, generated by oxidation of elemental sulphur and reduction of ferric iron in goethite matrix by *A. ferrooxidans*. Forty one percent of the nickel present in COB was extracted in a 3 L scale bioreactor (pH of 1.8 ± 0.05, temperature of 28 ± 2 °C) maintained in anoxic environment. In contrast, only 11% of the nickel present in COB was extracted with continuous supply of air to the bioreactor keeping all the parameters unchanged. Kinetics study of anoxic microbial processing of COB revealed that the chemical reaction rate control model fits to the rate of nickel dissolution (R^2 = 0.975).

1. Introduction

Mining waste was considered as the mineral containing materials no longer required for extraction of metals in industrial scale. The ore to waste ratio in surface mining ranges from 1:2 to 1:6 depending upon peripheral conditions (Karpe, 2011). Being a mineral rich country, India has generated around 1840 million tonnes of mining waste in year 2005–06 alone (Sahu and Dash, 2011). Sukinda valley in the state of Odisha is one of the major chromite reservoirs of the world and is the only known deposit of nickel in India (Murthy et al., 2010). Chromite mining at Sukinda valley annually generates around 6–7 million tonnes of lateritic chromite overburden (COB) containing nickel (0.5–1.0%) (Swain et al., 2007). Nickel ores are generally classified into two types i.e. (i) sulphide and (ii) lateritic (oxidic) type. The sulphidic ores are industrially exploited for extraction of nickel throughout the globe. Whereas, the lateritic (oxidic) ore is hardly utilised because of its mineralogical complexities hence regarded as waste. Furthermore, unexploited lateritic deposits in the earth crust have occupied the most abundant reserves (>70%) of nickel existing in the globe (Dalvi et al., 2004; Simate et al., 2010). Nickel present in laterites lack discrete mineral phase rather it is closely embedded with iron mineral matrixes [(goethite, FeO(OH)] (Swamy et al., 2003). Because of such mineralogical complexities the conventional pyro-metallurgy and hydro-metallurgical technologies have not been so far industrially accepted for extraction of nickel from laterites (Valix et al., 2001). However, due to rapid increase in nickel consumption coupled with gradual depletion of sulphidic mineral reserves of nickel, exploitation of the laterite deposits for the extraction of nickel has become the need of the day. In hydrometallurgical operations, extraction of metals from lateritic minerals is generally conducted through solubilisation of metals by mineral acids (sulphuric, hydrochloric acids). However substantial amount of metal recovery from laterites have been achieved only through thermal pre-treatment of laterites, using higher concentrations of acids and leaching at elevated temperature (Li et al., 2009; Luo et al., 2010; McDonald and Whittington, 2008; Girgin et al., 2011). In this context microbial processing

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