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Bioleaching of Alumina from Partially Lateritised Khondalite using Iron oxidizing bacteria

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ABSTRACT

The chemolithotrophic bacteria *Acidithiobacillus ferrooxidans* has been exploited world wide for various metallurgical phenomenon. Since these microorganisms thrive well in extreme environmental conditions hence these bacteria show certain tolerance limit to various heavy metal ions. In the current study bioleaching of alumina was carried out from partially laterized khondalite (PLK) using these iron oxidizing bacteria. Various leaching parameters such as pulp density, pH and temperature were studied to evaluate their effects on the leaching efficiency.

1. Introduction

Employment of microorganisms to recover metal values is free from environmental concerns unlike conventional hydrometallurgical methods. The main advantage in the bio-hydrological techniques is the ease of operation as well as limited use of process control, thus making the operation more users friendly (Pradhan *et al*., 2010).

Bio-hydrometallurgy is commercially exploited in the recovery of copper and uranium and is also used in the recovery of finely disseminated gold from refractory ore like pyrite and arsenopyrite (Pinches *et al*., 1997; Schnell, 1997; Brierley and Brierley, 2001). Bacterial oxidation of sulphide ores using chemoauto-trophic bacteria such as *Acidithiobacillus ferrooxidans* and *Acidithiobacillus thiooxidans* is a well-known process in bio-hydrometallurgy and thought to occur by a combination of direct and indirect mechanisms (Jain and Sharma, 2004).

Acidithiobacillus ferrooxidans is an acidophilic bacterium which can either grow on reduced sulphur compounds or on ferrous iron. It utilises energy obtained from oxidation of inorganic sulphur compounds (e.g. Fe_2S, CuFeS) as well as ferrous iron dissolved in a liquid medium. Ferrous iron is oxidised to ferric iron in acidic medium by means of *A. ferrooxidans*, while its chemical oxidation by means of oxygen is extremely low (Das *et al.,* 1998).

Partially Laterized khondalite is a waste material generated during the mining of bauxite. About 5 million tones of Bauxite is being processed by NALCO each year, for this amount of bauxite a lot of mine waste is generated and dumped at the mining site (Swain *et al.,* 2010). Most of these mining waste materials are PLK rock containing kaolinite, bauxite in varying proportions with minor amounts of hematite, goethite and rutile. The PLK contains about 45–56% Al_2O_3, 0.3–30% Fe_2O_3, 0.97–3%, TiO_2, 20–30% SiO_2 and 20–30% LOI. (Swain *et al.,* 2010).

The aim of this work is to evaluate the possibility of leaching alumina by iron oxidizing bacterial strains. There are many factors which can affect bioleaching kinetics. Some of those factors are pH, nutrient concentration, pulp density, reaction time, metal toxicity, temperature, etc. The present study discusses the effect of various leaching parameters on the efficiency of a mixed culture of iron oxidizing bacteria predominantly *Acidithiobacillus ferrooxidans*.

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2. Materials and methods

2.1 Mineralogical characterization

PLK samples were procured from bauxite mines of National Aluminium Company (NALCO), Damanjodi, Orissa, India. The mineralogical studies were carried out by X-ray diffraction methods. The mineralogical phase analysis was carried out using PANalytical X-pert X-ray Diffractometer with Mo-Ká radiation (ë=0.709 ú) from 6^0 to 40^0 scanning angle at a scanning rate of 0.02^0/sec. Complete chemical analysis of the sample was carried out by X-ray florescence (Mishra *et al*., 2011).

2.2 Microorganisms

A mixed laboratory stock culture consisting predominantly *Acidithiobacillus ferrooxidans* was used for the experiment. The generation time was reduced and the ferrous oxidation rate was fastened by repeated subculture of the consortia in $9K^+$ medium (Table 1). The growth pattern of the bacteria was analyzed by estimating the ferrous in the growth medium. The ferrous concentration was estimated by a titration method using, 0.1 N potassium dichromate as titrant and barium diphenylamine -4-sulfonate (BDAS) as a redox indicator.

Table 1
Composition of $9K^+$ medium used to culture *Acidithiobacillus ferrooxidans*

Components	Amount (g/l)
$(NH_4)SO_4$	3
KH_2PO_4	0.5
KCl	0.1
$MgSO_4.7H_2O$	0.5
$FeSO_4.7H_2O$	44

2.3 Bioleaching studies

All bioleaching experiments were performed 250 ml Erlenmeyer flasks. Each flask contained 90ml of $9K^+$ medium and 10ml of inoculum. A centrifugal incubator- shaker was used for the bioleaching experiments with a fixed speed of 150 rpm. Samples were collected at regular intervals for the analysis of pH and concentration of metal ions. The analysis of the metals was carried out by ICP-OES. Effects of various parameters on the leaching process were studied. Parameters like contact time, pulp density, pH, temperature and particle size were studied to obtain optimum conditions for the maximum recovery of the targeted metals from the waste. Other than the specified parameters rest of the parameters were maintained at: Fe (II), 10 g/l; pH, 2; pulp density, 10%, temperature 35^0C, particle size, 200 µm and 150 rpm.

3. Result and discussion

3.1 Mineralogical analysis

The sample was light yellow in colour. Mineralogy by *X*-ray diffraction pattern studies indicated that the PLK rock samples consist of mostly aluminium-bearing minerals like gibbsite, Kaolinite. Some other associated opaque minerals like goethite, hematite, ilmenite/altered ilmenite, rutile and graphite were also identified. Quartz, orthoclase and minor amounts of biotite form the silicate gangue minerals (Fig. 1). Microscopic studies showed that a higher percentage of quartz is present as the cavity fillings whereas biotite flakes of are present along with the orthoclase. It is observed in many places that orthoclase has been completely altered to a mass of kaolin. Gibbsite usually occurs as coarse to fine grains or clusters.

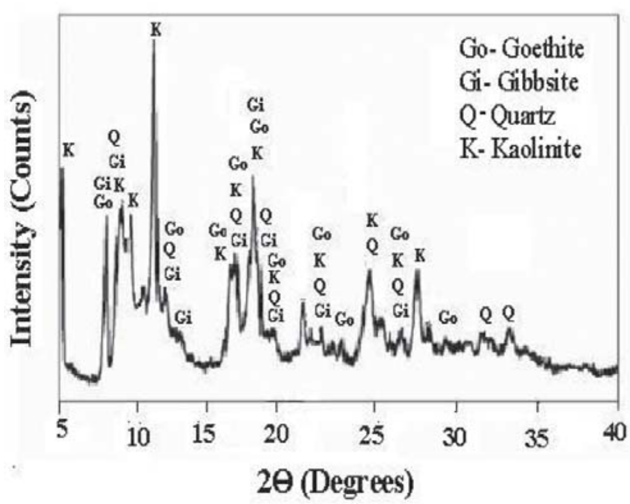

Fig. 1. Mineralogical analysis of PLK by XRD

3.2 Bioleaching studies

Pulp density is an important parameter involved in determining the process feasibility. The leaching studies were carried out by varying the pulp density from 5 to 25% (5-25 g of ore in 100 ml of medium).The leaching efficiency decreased with the increase of pulp density (Fig. 2). 63% alumina leaching was observed at 5% pulp density which decreased to 35% at 25% pulp density. The Eh values of the solution at 5 and 25% pulp density were around 600 and 500 mV respectively, showing less oxidizing condition at higher pulp density. The iron precipitation rate also increased with the increase of pulp density. This may have occurred due to improper mixing of the particles with the lixiviant, and inadequate diffusion of oxygen which may have decelerated bacterial growth or improper growth of bacteria in higher pulp density. The solubility of oxygen in water is 8 g/m^3 and it decreased with the increased ionic concentration in the

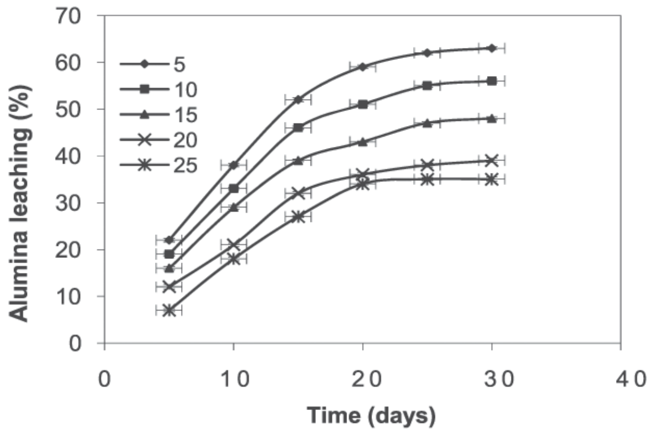

Fig. 2. Effect of pulp density (g/100ml) on alumina leaching from PLK

solution (Karavaiko *et al.,* 1988) which hinders the further growth of the bacteria. Poor heat and mass transfer might be the other reasons for the lower leaching at higher pulp density.

To evaluate the effects of acidity, the initial pH was varied from 1.5 to 3. The leaching efficiency was higher at lower pH values. The alumina leaching was 58% at 1.5 pH which gradually decreased with increase in pH (Fig. 3) The iron precipitation rate increased with the increase of pH. Numerous studies have demonstrated that bioleaching of the minerals occur favorably pH< 3. At pH<3 the regeneration of Fe^{3+} via biological oxidation of Fe^{2+} is of

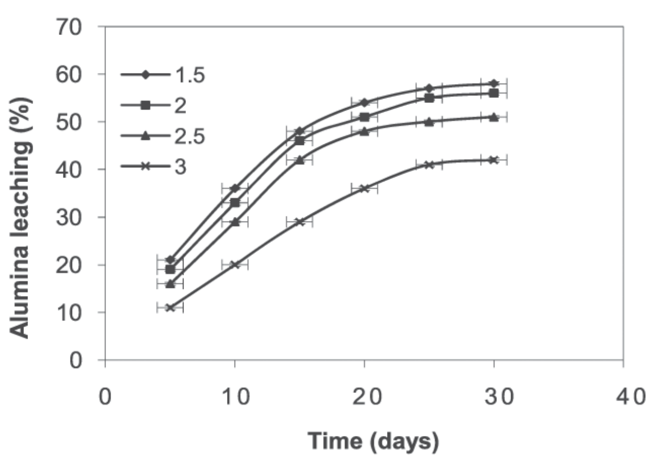

Fig. 3. Effect of pH on alumina leaching from PLK

great importance due to negligible abiotic oxidation of Fe^{2+} (Stumm and Morgan, 1981) The Eh of the solution in all cases varied in the range 550–650 mV indicating good oxidizing conditions.

Temperature is an important environmental factor that influences bacterial activities in biological leaching operations (Kelly and Tuovinen, 1998). In the present study the temperature was varied from 15 to 45^{0}C. The leaching efficiency increased with the increase of reaction temperature, thus indicating the dissolution process to be endothermic in nature. At the highest temperature the leaching decreased due to lesser adaptability of the organisms. At the lower temperatures the organisms used in the experiment became metabolically dormant but at higher temperatures they were rapidly destroyed as they are mesophilic in nature and therefore gave the best leaching results at 30-35^{0}C. The maximum leaching of alumina obtained at the moderate

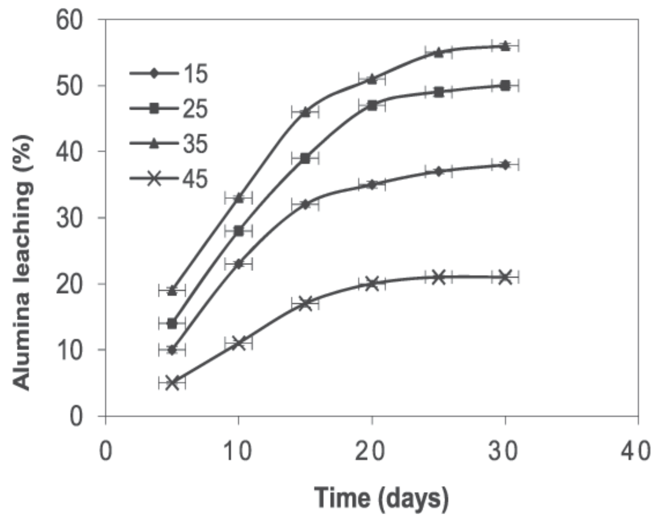

Fig.4. Effect of temperature (^{0}C) on alumina leaching from PLK

temperate range was around 55-56%. The leaching results are shown in Fig. 4. The iron precipitation rate increased with the increase of reaction temperature.

Leaching of alumina from different ores and waste materials using heterotrophic microorganisms have been reported through many studies (Mishra *et al*., 2009) but there are few studies showing extraction of alumina using mesophilic chemolithoautotrophs. Solisio *et al.* (2002) reported bioleaching of Zn and Al from industrial waste sludges using *A. ferrooxidans.* They achieved around 78% of alumina extraction. Bojinova and Velkova (2001) worked with industrial waste product for extraction of different valuable metals. A maximum of 71% of extraction was observed on 28th day of the experiment with *A. ferrooxidans*.

4. Conclusion

In this study, experiments were conducted to evaluate the leaching efficiency of Alumina from Partially Laterized Khondalite using iron oxidizing bacteria. The dissolution process followed dual kinetics, i.e., an initial faster rate followed by a slower one, attaining equilibrium after 10 days of reaction time. The initial concentration of Fe(II) played an important role in determining the leaching efficiency. The leaching efficiency decreased with increase of pulp density, probably due to improper mixing or an increase of iron precipitation rate or lack of oxygen or combination of all these factors. Acidity and temperature also played an important role in determining the leaching efficiency.

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