THE RECENT TRENDS AND PERSPECTIVES OF LEACHING OR BIOLEACHING FROM NICKEL OXIDIXED ORES

Boris Krstev[1], Dejan Krstev[1], Aleksandar Krstev[2]
[1]Goce Delcev Universiry, Faculty of Technical&Natural Sciences, STIP, The Republic of Macedonia
[2]Goce Delcev Universiry, Faculty of Informatics, STIP, The Republic of Macedonia
boris.krstev@ugd.edu.mk

Abstract: The refractory or low grade nickel oxidized domestic ores (laterites) in Republic of Macedonia are investigated by conventional magnetic separation technology or segregation-flotation-magnetic separation, or production and smelting to ferronickel. In the mean time, investigations are directed to the new possibilities of leaching by microorganisms – bioleaching. The paper is result of these technologies and investigations carried out for recovery of in the mentioned ores. The average recoveries from leaching were cca 87-90% for nickel and the average recoveries from bioleaching were cca 93-95% for nickel.
key words: leaching, bioleaching, HPAL, chemolithotrophic microorganisms

Introduction

A combination of recent or current trends and developments may undermine the sulphides supremacy and might tip the balance of oxide-silicated ores – garnierites and laterites for new investigations. The previous laterite operations or laterite processing were following: Ferronickel smelting, Matte smelting, Reduction roast-ammonia leaching and High pressure sulphuric acid leaching. Apart from the above mentioned processes possibilities, there have been many attempts to develop alternative processes which have included: Nitric Acid Leaching, Chlorine Leaching, Acid Pugging and Sulphation Roasting, especially Segregation Process with combination of Flotation, Magnetic Separation or Leaching etc.

Leaching and bacterial leaching

Future sustainable development requires measures to reduce the dependence on nonrenewable raw materials and the demand for primary resources. New resources for metals must be developed with the aid of new developed technologies, improvement of already existing techniques resulting in metal recovery from sources that have not been of economical interest until today. Metal-winning processes based on the activity of microorganisms offer the possibility to obtain metals from mineral resources not accessible by conventional mining. Microbes such as bacteria and fungi convert metal compounds into their water-soluble forms and are biocatalysts of these leaching processes. Also, applying microbiological solubility processes, it is possible to recover metal values from industrial wastes which can serve as secondary raw material.

Generally speaking, these processes as bioleaching is described as being “the dissolution of metals from their mineral sources by certain naturally occurring microorganisms” or “the use of microorganisms to transform elements so that the elements can be extracted from a material when water is filtered through it”. Worldwide reserves of high-grade ores are diminishing due to the rapid increase in the demand for metals. However, there exist large stockpiles of low and lean grade ores yet to be mined. The problem is that the recovery of metals from low and lean grade ores using conventional techniques is very expensive due to high energy and capital inputs required. Another major problem is environmental costs due to the high level of pollution from these techniques. Environmental standards continue to stiffen, particularly regarding toxic wastes, so costs for ensuring environmental protection will continue to rise.

Biotechnology is regarded as one of the most promising and certainly the most solution to these problems, compared to pyro - metallurgy or chemical metallurgy. It holds the promise of dramatically reducing the capital costs. It also offers the opportunity to reduce environmental pollution. Biological processes are carried out under mild conditions, usually without addition of toxic chemicals. The products of biological processes end up in aqueous solution which is more amenable to containment and treatment then gaseous waste.

Bacterial leaching is possible with low concentrations and requires little energy inputs. The process is environment friendly even while giving extraction yields of over 85-90%.

Occurrence of nickel in oxide-silicated ores

For the metallurgical calculation nickel in the oxide-silicated minerals may be shown by means of the general formula:

$$NiSiO_3.\ m\ MgSiO_3\ .\ n\ H_2O$$

Or by possible transformation:

$$(Si_2O_5)^{2-} \rightarrow (SiO_4)^{2-} \rightarrow (SiO_3)^{2-}$$
$$NiO.2SiO_2 \rightarrow 2NiO.SiO_2 \rightarrow NiO.SiO_2$$
Olivine → Piroxen

The amorphous crystal structure is transformed to the stable crystal structure. The iron in the Ni- bearing minerals and ores is appeared as $Fe_2O_3.nH_2O$ and as a nontronite $(Fe/Al)_2(Si_4O_{10})(OH_2).nH_2O$. The oxide-laterite ores are with low Ni-content. The generally, nickel and iron are as Ni-Fe- limonite $(Fe, Ni)O(OH).nH_2O$, garnierite or in the talc form $(Mg, Ni, Fe)_3Si_4O_{10}(OH)_2.nH_2O$.

Serpentine: $\mathbf{Mg_6(Si_4O_{10})(OH)_8}$

= → $\mathbf{(Mg,Fe^{2+},Ni)_{6-x}[Si_{4-x}(Fe^{3+},Al,Cr)_x o_{10}](OH)_8}$

Fe^{2+}, Fe^{3+}, Al, Cr	Fe^{3+}, Al, Cr

Talc: $\mathbf{(Mg, Ni)_3 (Si_4O_{10})(OH)_2 . H_2O}$

= → $\mathbf{(Mg, Ni)_3 [Si_{3,75},Al_{0,25}, O_{10}](OH)_2.H_2O}$

Fe^{2+}, Fe^{3+}	Fe^{3+}, Al, Cr

Garnierite : (Ni, $\mathbf{Mg)_6 (Si_4O_{10})(OH)_8.4H_2O}$

Nontronite : $\mathbf{(Ni, Fe, Al)_2(Si_4O_{10})(OH_2).nH_2O}$

Experimental part

It's fact that the hydrometallurgy processes are more applicable to the limonitic laterites or garnierite's. Although the saprolit laterites are often richer in nickel than the limonitic ores, the high Mg content results in higher acid consumption. The theory confirmed that primary hydrometallurgy processes are the Caron process, HPAL (high-pressure acid leaching) or atmospheric-pressure acid leaching process.

In the investigated HPAL, limonitic mixture ores are leached at high pressure (33-35 bars) and temperature (240-270^{o}C) in autoclave, with slurry densities of about 20%, and acid consumption or acid to ore ratio of 200-500 kg/t ores. The (temperature 250-270 ^{o}C interaction effect of one factor on the response of another, generally **A** (temperature 250 ^{o}C) by **B** (or acid to ore ratio of 200-500 kg/t ores) effect is the change in the effect of A as B goes from – to + values (plan of experiments 2^3). There are 16 data points on each chart and the interpret the interaction plot is simply. In the case of the 2^3 or 2^4 plan of experiments the magnitude and direction of the effect can be determined from the relative location of the appropriate data points.

The bio-hydrometallurgy, especially bioleaching, bacterial leaching or microbial technology is a promising novel technology for recovering the nickel from nickel laterites (valuable minerals traditionally difficult-to-process ores) using chemolithotrophic microorganisms**.**

Results and discusion

Table 1. Investigation by HPAL process

SAMPLE	**A**	**B**	**R_{Ni}%**
1	250	O.24	78,50
2	250	0.40	91,10
3	270	0.24	82,35
4	270	0.40	94,55
5	260	0.32	91.50
6	260	0.40	92.75
7	255	0.32	82.10
8	255	0.40	92.00
9	265	0.24	90.50
10	265	0.28	90.80
11	265	0.32	91.70
12	265	0.36	91.90
13	270	0.35	92.30
14	270	0.40	93.30
15	270	0.45	94.75
16	270	0.50	95.10

Table 2. Investigation by bioleachiing process

SAMPLE	Adding %	Days	**R_{Ni}%**
1	1.50	30	83.50
2	1.50	45	92.90
3	1.70	30	90.35
4	1.65	45	93.55
5	1.65	30	91.09
6	1.70	45	92.75
7	1.60	30	93.30
8	1.60	40	94.55
9	1.60	50	91.10
10	1.60	60	92.70
11	1.65	40	93.00
12	1.65	50	93.50
13	1.70	30	92.50
14	1.70	40	92.75
15	1.70	50	93.35
16	1.70	60	94.70

Apart from the above mentioned processes routes, there have been many attempts to develop processes known as alternative processes which have included:

Nitric Acid Leaching, Chlorine Leaching, Acid Pugging and Sulfation Roasting, especially Segregation Process with combination of Flotation, Magnetic Separation or Leaching etc. Nickel laterite is not capable of participating in the primary chemolithotrophic bacterial oxidation because it contains neither ferrous iron nor substantial amount of reduced sulfur. Recovery is allowed with the primary oxidation of pyrite, or similar iron/sulfur minerals to provide sulfuric acid solutions which nor solubilize the present metal content. It's very important to know the role of the sulfuric acid. The results showed that this acid performed better, in terms of R_{Ni}%, then citric acid or ferric sulfate of the same initial concentration. Using appropriate optimization strategy or methodology, the theoretical optimum conditions for maximum R_{Ni}% (*more then 85-90%*) within the range of operational conditions in the presence of mentioned bacteria or fungi, pH-2,0, particle size of the samples less than 63 μm, pulp density-2,5%. Bacterial leaching with chemolithotrophic microorganisms recoveries from R_{Ni}% (85-95%).

Conclusion

The experimenting between leaching and bacterial leaching have showed the following results: leaching with *HPAL* process and recoveries from R_{Ni}% (80-95%) and bacterial leaching with chemolithotrophic microorganisms recoveries from R_{Ni}% (85-95%).

Literature:

Journal:

[1] A.D. Dalvi, W.G. Bacon and R.C.Osborne, "The past and future of nickel laterites", PDAC 2004 International Convention, March 7-10, 2004, pp 1-27

[2] D. Gerorgiou and V.G. Papangelakis, "Sulphuric acid pressure leaching of a limonitic laterite: chemistry and kinetics", Hidrometallurgy, 49, 1998, pp 23-46

[3] D. Gerorgiou and V.G. Papangelakis, "Sulphuric acid pressure leaching of laterites – speciation and prediction of metal solubilities at temperature", Hidrometallurgy, 58, 2000, pp 13-26

[4] S. Stopic, B. Friedrich and R. Fuchs, "Kineteics of sulphuric acid leaching of the Serbian nickel lateritic ore under atmospheric pressure", 2001, MJoM, Erzmetall, pp 235-244

[5] S. Stopic, B. Friedrich, N. Anastasijevic and A. Onjia, "Experimental design approach regarding kinetics of high pressure atmospheric leaching", 2002,MJoM, Erzmetall, pp 273-282

Patents:

[6] J.C. Arroyo and D.A. Neudorf, "Atmospheric leach process for the recovery of nickel and cobalt from limonite and saprolite ores", US Patent 6, 680, 035, Jan 20, 2004

[7] W.P.C. Duyvesteyn, D.A. Neudorf and E.M. Weeniink, "Resin-in-pulp method for recovery of nickel and cobalt", US Patent 6, 350, 420, Feb 26, 2002