State of the Art of Ni-Production in the Balkan Region with Special Focus on Ni-loss in Slags

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Abstract

Resources of lateritic nickel ores are enormous in the Balkan area. However, an environmentally friendly technology is required for nickel production in the future. Using reductive smelting in Electro Reduction Furnaces (ERF) Larymna Larco; FENI, Kavadarci and Feronickel Glogovac belong to the most known producers of ferronickel in the Balkan area. Due to the difficult market situation and the strict environmental regulations, the production of ferronickel was decreased in the period between 2005 and 2010.

The production of ferronickel leads to “metallurgical wastes” of about 2000 kt/y of ERF slag (approx. 0.26 % NiO), 180 kt/y rotary kiln gas-cleaning dust and 120 kt/y of converter slag at Larco alone. The slag produced at Larco during the refining is a by-product, which is sold as heavy inert material for the production of special type of concrete and for covering of oil tubes or other similar applications in Europe. In order to produce cement material a semi-industrial recycling unit for used ferrous-nickel slag was designed and installed in a Greek shipyard. The most important contribution to recycling of these wastes is made by the local cement industries, which are using about 25 % of the slag in the production of Portland cement. Unfortunately a treatment of ferronickel slag aiming at the recovery of nickel is not yet available. Hydrometallurgical treatment of lateritic ore in order to produce a mixed Ni/Co hydroxide was performed by European Nickel, England.

Keywords: nickel, slag, recycling, ferronickel, Balkan

1 Introduction

The Balkan represents a peninsula of southeast Europe bounded by the Black Sea, the Sea of Marmara, and the Aegean, Mediterranean, Ionian, and Adriatic seas. The Balkan States are Albania, Bosnia and Herzegovina, Bulgaria, Croatia, continental Greece, Former Yugoslav Republic of Macedonia (FYROM), Montenegro, southeast Romania, Serbia, and European Turkey. Laterites and other oxidized nickel ores constitute a very important part of nickel reserves in the Balkan area.

This paper offers the newest information about nickel production, quantities of formed dust and slag, their treatment, losses and the recovery yield of nickel as well as potential usages of the formed slag. The considerable increase in growth and interest in extractive metallurgy of nickel in the Balkan area as a whole requires a permanent analysis of state and development of Ni-production with special focus on Ni-loss in slag. Generally speaking economics and the technologies which support economic progress are crucial in solving many problems we face. In this millennium, mutual understanding and cooperation between nations in the Balkan area must be pointed out more strongly than in the past. We found that it is no longer possible for single nations to enjoy stability and prosperity in isolation from the rest of the world. We would like to offer the localisation of important production facilities in the Balkan area

in a way which might help in solving the nickel extraction. One of our aims is a review of problems resulting from mining and metallurgical production of nickel in the Balkan area offering an approach from various angles in order to consider possible recycling and hydrometallurgical ideas as an essential development task for future methods of metal production.

2 State of the art of nickel production

Ni occurs naturally as a component of sulphide deposites or as laterite ores. FeNi production copes for more than one third of virgin nickel used in stainless steel production. The ratio of nickel scrap has increased from 651 tons in 2003 to 741 tons in 2005.

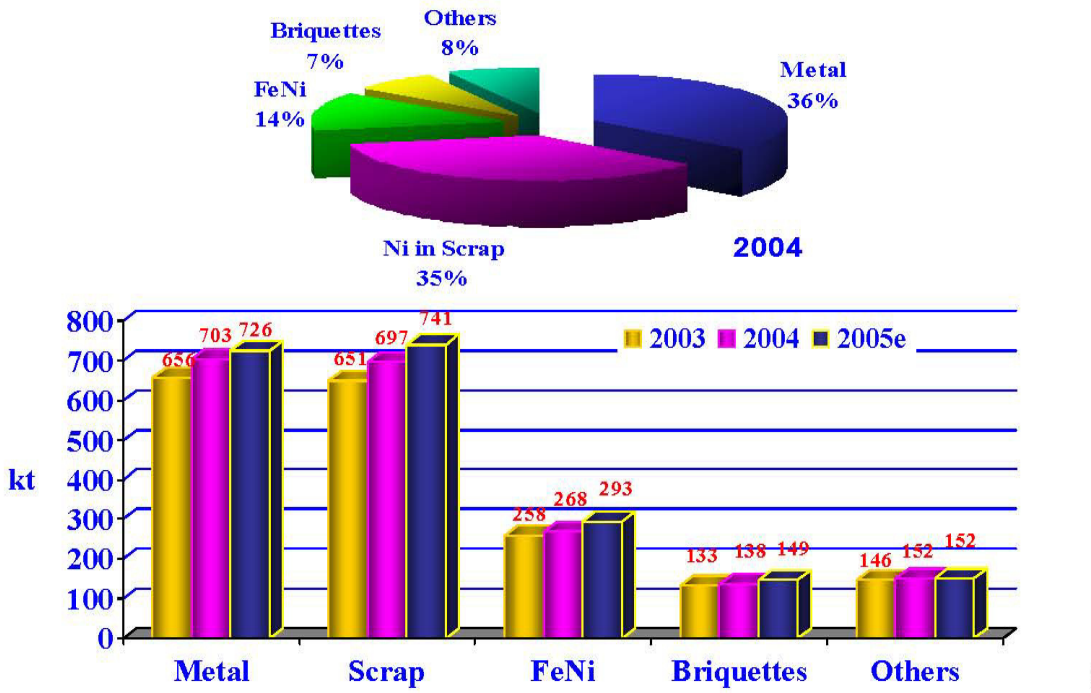

Figure 1: World nickel supply by products in period between 2003 and 2005

The increase of FeNi production follows an increase of stainless production.

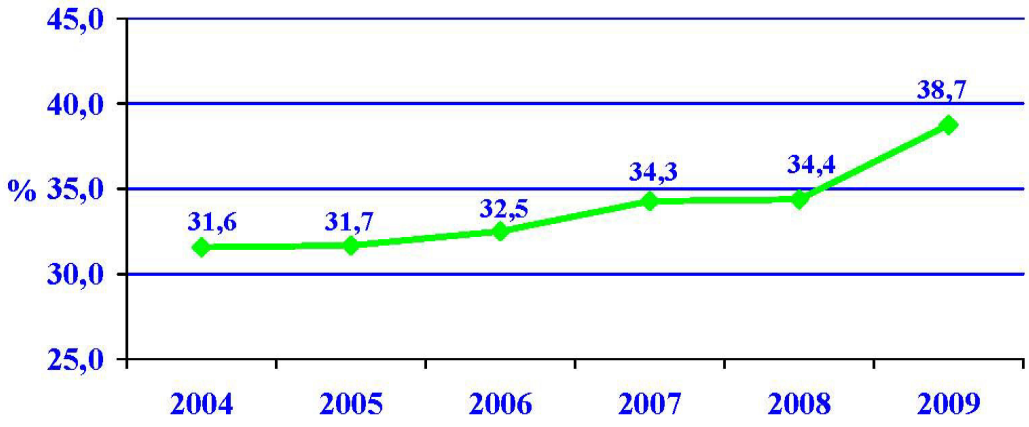

Figure 2: FeNi world market share in the production of stainless steel [1][2]

In the Balkan laterite resources with 1 % Ni are enormous and FeNi-production is available in Greece (Larco, Athens), Kosovo (Ferronikeli, Glogovac) and Former Yugoslav Republic of Macedonia (FENI, Kavadarci). However, increased industrial production during the last few years while implementing new environmental legislation, forced the respective metallurgical industries to find either new applications or a better disposal solutions for their generated residues (waste dust and slag).

Figure 3: Chance for new cooperation in nickel metallurgy in the Balkan area

The reduction smelting of low grade nickel ores in Electro Reduction Furnaces (ERF) is generally characterised by the production of large slag quantities and high energy consumption per ton of metal or metal alloys produced. The production of ferronickel from laterites as practised nowadays at “LARCO”, Larymna, Greece, is a typical example of such a metallurgical process [2]. For production of 1 t of FeNi with 15 % Ni is accompanied with generation of about 20 t of slag [2].

Mickovski and Dudokovska [3] point out the influence of charging ignite on prereduction parameters on nickel-ore pellets and their optimisation in the process of producing FeNi from laterite in “FENI” Kavadarci, FYROM. As a result of the ever increasing cost of nickel production associated with traditional pyrometallurgical techniques has led to increased environmental pollution, and the depletion of high-grade sulphide ores, so that renewed interest has been recently developed concerning the production of nickel from laterite deposits using hydrometallurgical processes. Lateritic deposits constitute 70 to 80 % of the earth known nickel resources and can be estimated at 22 billion tons worldwide. Regarding to the laterite resources in Balkan area, the following information is found:

1. Greece - Larymna -120 million tons,
2. former Yugoslavia with five regions: a) West Morava- 35 million tons, b) Zlatibor 150 million tons, c) Sumadija 11 million tons, d) Kosovo 10 million tons, Rzanovo (in FYROM) – 100 million tons,
3. Albania – 10 million tons.

Although sulphuric acid pressure leaching (SAPL) of oxidic nickel ores is the process of choice to recover nickel and cobalt from lateritic ores, replacing the energy intensive pyrometallurgical methods [4], it has not seen any application in the Balkan area in order to produce nickel. The SAPL process as run in Australia for example achieves a high nickel and cobalt extraction (more than 95 %) with a high selectivity due to simultaneous iron and aluminium dissolution and precipitation.

Davidson [5] found that in the period between 2006 and 2011 the production of nickel from sulphide ores is declining. She reported that the Chinese have become large buyers of sulphide intermediates. Sulphide deposits are being used up at a faster rate than they are being replenished. Not only is the quantity of the sulphide-bearing ore declining, but so are the ore grades too. Almost 20 % of new sulphide production will represent replacement feed. To guarantee the future supply of nickel, the industry must develop laterite ore bodies, especially limonite deposits utilising HPAL technology.

2.1 The production of FeNi in Larymna Larco, Greece

Nickel is extracted from Greek laterites by a pyrometallurgical process (Larco process) based on the technical know-how and industrial practice established after 1st commissioning 45 years ago. The main content of iron and nickel mineral phases in the Greek nickeliferrous laterites, are hematite and goethite for the iron and chlorite and serpentine for nickel. The metallurgical process applied to these laterites for Fe-Ni production, involves the following steps:

- Handling and mixing of raw materials (i.e., laterite, pellets, solid fuels and crushed agglomerated rotary kiln calcine),
- Roasting reduction (drying, pre-heating and pre-reduction) of laterite, pellets and crusher product in rotary kilns (R/K) and production of a calcine, the so called PEK.
- Reductive smelting of the calcine (PEK) in open-bath submerged-arc electric furnaces (E/F) and production of Fe-Ni alloy with 12–16 wt.% Ni.
- Refining and enrichment of Fe-Ni with 12–16 wt.% Ni to Fe-Ni with 18–25 wt.% Ni, in OBM converters

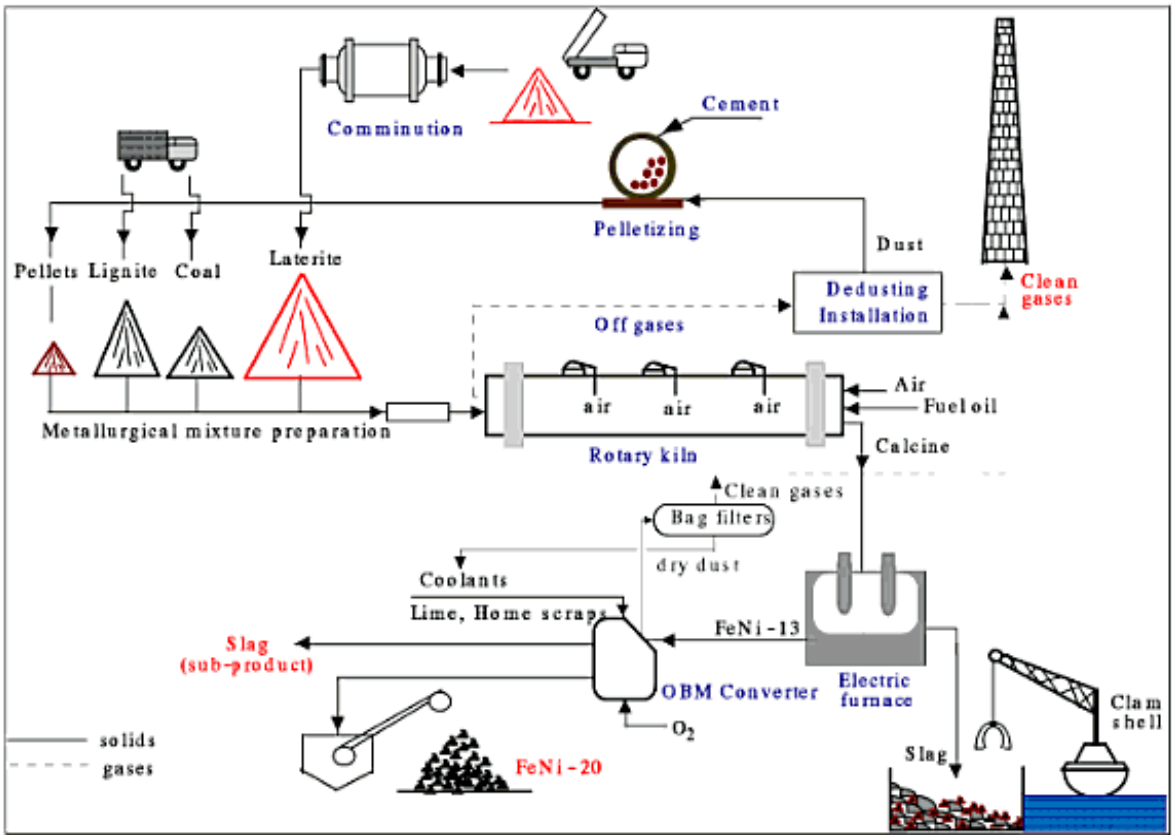

Figure 4: Flowsheet of ferronickel production in Larymna, Larco

Larco has three main mining areas: Evia (open pit), with an annual production of about 1.5 Mt of ore; Agios Ioannis (underground), with an annual production of about 700,000 t of ore; and Kastoria (open pit), with an annual production of about 300,000 t. Annual production of nickel met about 6 % of the European market demand in 2005. The Larymna Larco plant in Greece processes nickelferrous laterite ores producing ferronickel with 18–24 wt.% Ni-content. The total quantity of ore processed is 2,500,000 t/year (around 18,000-20,000 t of Ni per year). The production of FeNi leads to “metallurgical wastes” of about 2000 kt/year of ERF slag (with approx. 0.26 wt.% NiO), 180 kt/y rotary kiln dust from gas-cleaning-system and 120 kt/y converter slag. As reported in 2004 a recovery of Ni contained in these slags and bauxite amounted up to 87 % in pilot tests. Electric furnace slag (EFS) is produced during reductive smelting and made up mainly of iron oxides and SiO_2 at a content of about 35 wt.% each, the rest being oxides of Ca, Mg, Al and Cr. Most part of carbon (57.9 %) and the volatiles are used for heating purposes and the rest (5.0 %) remains in dust, coatings and slag.

The slag produced during refining is a by-product, which after milling to a size of 5 mm, is sold as heavy inert material for the production of a special type of concrete and for covering of oil tubes or other similar applications in Europe. A semi-industrial recycling unit of used ferrous-nickel slag was designed and installed in a Greek shipyard (Neorion New SA of Syros Shipyards). This operation was verified from laboratory tests and has proven to be profitable. The most important contribution to the recycling of these wastes is made by local cement industries, which are using about 25 % of the above-mentioned slags in the production of Portland cement. The Greek cement industry invests in modern technology resulting in the gradual reduction of the specific fuel consumption per ton of produced clinker and consequently in the re-

duction of the carbon dioxide emissions per ton of treated nickel slag. However Larco – Greece, has reduced production of ferronickel by 55 % in 2009 most likely due to a drop in demand following the economical crisis.

Figure 5: Electric furnace slag (EFS) produced during reductive smelting in Larco

2.2 Ferronickel plant FeNi, Kavadarci, FYROM

"FENI" Plant in FYROM was built in 1978 at investment costs of about 600 million USD. Until 2000, the combine worked with interruptions. Its operation was stopped for the first time in 1980 because of the low world price of nickel. In 1990 the combine was taken over by the consortium "FENIMAK" composed of strong domestic firms. It worked until 1998 when it suffered some 100 million DM worth losses. Since 1998 till last march the combine was financed by the state, and its workers were the only ones of all Macedonian firms to receive their wages from state budget. Then, at the insistence of the International Monetary Fund, the government had to stop financing "FENI". Its capacity is designed for the production of 11,000 tons of nickel per year. The government has managed to improve its rating by keeping jobs of 880 workers, while the work of "FENI" will secure wages for additional 1,000 people in other firms which indirectly depend on the combine.

In 2000 the French company "Societe Comercial de Metals at Minerals" SCMM bought "FENI" Nickel combine for 2.25 million USD and the French have undertaken investments of 36 million USD over five years in the form of capital inflow, modernization and expansion of production of the combine which is a unique nickel producer in the Balkans. The French have also taken upon themselves to keep all 880 employees and to pay the electricity bill at the rate of 22 USD per MWh on which they signed a three-year contract with the Macedonian Power Generating and Distributing Company worth 25 million USD. SCMM was one of three firms (also interested were the British "Imperial Metal" and Swiss "Glenkor") which submitted their offers for the purchase of "FeNi".

In 2006 two foreign companies - "Benny Steinmetz" – South Africa and London-based "Alferon" - have become new owners of "FeNi-Industry" for 14 million USD. They presented their plan to invest 25 million USD in the company, which will double the production of 7,000 t of ferronickel in the next year.

Ferronickel plant FENI, Kavadarci is supplied with Ni-ores from varying group's mines (Indonesia, Albania, New Caledonia and Turkey) and plans to raise its output

to 14,000 tons in 2010 from the 11,400 tons produced last year. Every year about 1,500,000 tons of industrial waste material: fly ash (0.02 % NiO) and metallurgical slag (0.30 % NiO) are produced in FYROM. The company also plans to export Ni-slag to abroad. The ratio between SiO_2 and MgO in slag amounts between 2.0 and 2.4.

Glass-ceramics composites are produced based on fly-ash obtained from coal power stations and metallurgical slag from the ferronickel industry. Ni-slag (air-cooled and granulated) is suitable for use as a granular road base material and has suitable engineering properties for use in embankment or filling applications. Kavadarci FeNi smelter – Macedonia, was reduced production by 80 % in 2009.

2.3 The production of FeNi in Ferronikeli, Glogovac, Kosovo

Ferronikeli ore mining and metallurgical complex was started on May 23rd 1984 to produce ferro-nickel for exports. It was built on the supply basis of local lateritic ore deposits with approximate contents (in wt.%) of 1.32 Ni, 24.0 Fe_2O_3, 46.0 SiO_2 and 28 H_2O [9]. Similarly to the process presented above in Figure 4, the technological process of ore melting in production of ferronickel contains the following operations:

1) batch preparation (grinding of ore, fluxing agent and reductant and mixing)
2) drying and prereductive ore calcining in rotary furnaces (two Smith type furnaces, Denmark)
3) melting and reductive ore calcination in electric furnaces (two ELKEM type furnaces, power 45 MW, secondary voltage 150-734 V) in order to produce crude ferronickel
4) crude ferronickel refining in converters in two desulphurisation steps
5) casting of refined ferronickel into ingots

The melting products are crude ferronickel, slag and gases. The ferronickel composition varies between 15 and 25 % of Ni. The slag from the electric furnace contains the following components (in wt.%): 0.11 Ni, 0.018 Co, 9.3 CaO; 14.8 MgO. The slag mass amounts to about 65–75 % of the batch mass. Produced gases are composed approximately by 50–70 wt.% CO and 30–50 wt.% CO_2 . The gases take away even a portion of the dust (about 1 %) formed which is recirculated to the process.

The plant produced and exported 6,800 tonnes per year of nickel, in ferro-nickel ingots, before the 1990's but since 1998 it has been idle. Ferronikeli has three open pit mines: the Dushkaja mine with estimated reserves of 6.2 million tons; the Suka mine with 0.8 million tons and Glavica with 6.8 million tons. It runs three open-pit mines with a total of estimated reserves of 14 million tons and employs around 1,000 workers producing about 600 t of FeNi per month. One major challenge is the humidity in the ore (about 40 %). An industrial drier is required in order to increase the production. All the mines in the complex were covered early this year with exploration and exploitation license by the Ministry of Energy and Mining of Kosovo.

Ferronikeli, Glogovac operates with ore from the group's mines in the country, as well as imports from Albania, charging blends to the production unit. The mining and metallurgical complex was badly damaged during the 1999 NATO air strike against Serbia and has meanwhile been bought by a consortium of IMR and Alferon for 30.5 million euro. The owners estimate that the complex can produce 10,000–12,000 tons of nickel per year.

Figure 6: Ferronickel plant in Glogovac, Kosovo

2.4 Ferronickel in Albania

The chain of Ni-laterite deposits (e.g. the Prrenjas basin in east Albania) always follows the boundary of serpentine and the cover of cretaceous limestone. In the last decade there is little accessible information about ferronickel production in Albania. Annual nickel output ranged from 7,200 to 9,000 tons in the 1980s. The metallurgical complex in Elbasan was closed in 1990, although there is still a scrap smelter working with obsolete equipment and technologies. About 1.5-2.0 million tons of stored FeNi slags contaminate soil and groundwater with heavy metals (chromium, nickel and manganese).

2.5 The production of nickel via hydrometallurgical method by European Nickel PLC, London

European Nickel is an emerging nickel laterite producer focused on growth. With over 1 million tons of nickel resources and assets in Turkey, the Philippines and Albania European Nickel is targeting 50,000 tonnes of annual nickel production within five years. The Caldag project in Turkey is the company's flagship asset with near-term production and will be the world's first commercial scale nickel laterite heap leach operation [7][8].

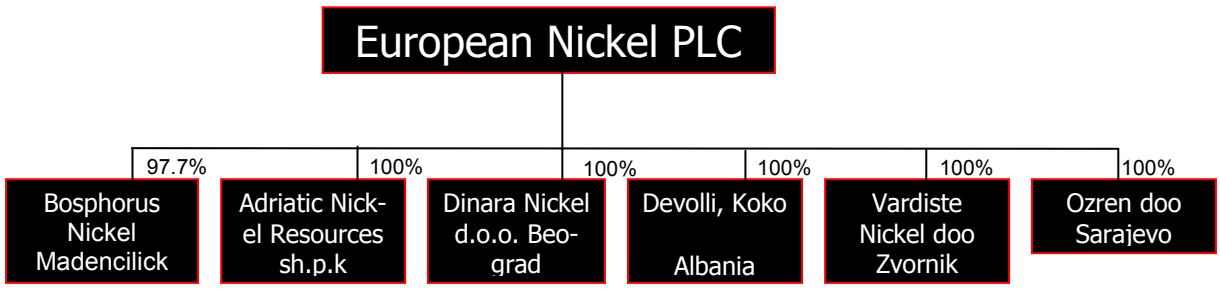

Figure 7: Working activities of the European Nickel PLC in the Balkan area

European Nickel is in a joint venture with the privately owned Balkan Resources to jointly develop Balkan's Kokogllave ("Koko") and the Company's contiguous Devolli

nickel laterite deposits in Albania. The deposits are located in south-eastern Albania, close to the Greek border. The Devolli nickel laterite deposit has a JORC resource of 427,000 tonnes of contained nickel of about 35.6 million tonnes at an average concentration of 1.20 wt.%. The final product of nickel processing is a mixture from nickel- and cobalt hydroxide.

3 Conclusion

The Balkan area is very rich on nickel lateritic ores. Using reductive smelting in Electro Reduction Furnaces (ERF) Larymna Larco, FeNi, Kavadarci, Feronickel Glogovac belong to the most known producers of nickel in this area. The production of ferronickel leads to “metallurgical wastes” of about 2,000 kt/y of ERF slag (approx. 0.26 % NiO), 180 kt/y rotary kiln dust from gas-cleaning-system and 120 kt/y of converter slag. The slag produced in Larco during the refining is a by-product, which after milling to a size of 5 mm, is sold as a heavy inert material for the production of special type of concrete and for covering of oil tubes or other similar applications in Europe. A semi-industrial recycling unit of used ferrous-nickel slag was designed and installed in a Greek shipyard (Neorion New SA of Syros Shipyards). The most important contribution to the recycling of these wastes is made by the local cement industries, which use about 25 % of the above-mentioned slags in the production of Portland cement.

European Nickel, London owns nickel lateritic resources in Albania, Serbia, Republika Srpska and in Croatia. Using a hydrometallurgical method European Nickel the company produces a product containing a mixture from Nickel- and cobalt hydroxide as intermediate.

Sulphuric acid pressure leaching (SAPL) of oxidic nickel ores might be the process of choice to recover nickel and cobalt from lateritic ores, replacing the energy intensive pyrometallurgical methods.

Due to environmental problems it is necessary to urgently propose either a suitable hydrometallurgical or pyrometallurgical recycling process for removal of nickel from the obtained slags from the ferronickel industry. At this moment, stored FeNi slags contaminate soil and groundwater with heavy metals (chromium, nickel and manganese).

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