Sulfur-enhanced reductive bio-processing of Co-bearing materials using acidophilic iron- and sulfur-oxidizing bacteria

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First of a kind commercial Compact system for the efficient Recovery Of Cobalt Designed with novel Integrated LEading technologies
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The CROCODILE Project

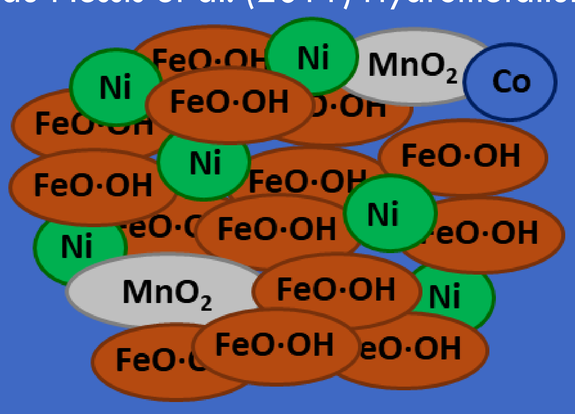
Challenge: Improve the economic and environmental values of **cobalt recovery processes** in Europe.

Solution: Provide a zero-waste strategy for important waste streams rich in cobalt.

Targeted feedstock: The targeted **primary** and secondary **raw materials are laterite ores**, autocatalysts and batteries.

The concept of Sulfur-Enhanced Reductive Bioleaching:

du Plessis et al. (2011) Hydrometallurgy, 109:3-4, 221-229



Limonitic laterite ore

(i) Reduction of goethite phase:

$6FeO{\cdot}OH(Ni) + S^0 + 11H^+ \rightarrow 6Fe^{2+} + HSO_4^{2-} + 8H_2O + Ni^{2+}$

(ii) Reduction of asbolane phase:

$(Ni,Co)_xMn(O,OH)_4.nH_2O + 2Fe^{2+} \rightarrow xNi^{2+} + xCo^{2+} + Mn^{2+} + 2Fe^{3+}$

Experimental set-up

Samples were collected from Ni-Co laterite deposits in Greece (L1-L5) and New Caledonia (NC1)

Samples	Metal content (wt%)			
	Co	Ni	Fe	Mn
L1- Filtering dust	0.06	1.13	18.0	0.26
L2 - Processing slag	0.01	0.11	28.2	0.26
L3 - Kastoria mine	0.03	1.02	16.0	0.23
L4 - Ag Ioannis mine	0.05	0.82	34.6	0.22
L5 - Evia mine	0.03	0.56	21.5	0.22
NC1 - PenaMax	0.04	0.31	23.1	0.45

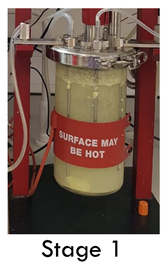
Reductive Bioleaching

Preliminary screening

Carried out with all samples using similar bioleaching conditions:

- 5% (w/v) pulp density
- pH 1.5 and 35°C
- Gassed with oxygen-free nitrogen (OFN)
- Inoculated with:

Acidithiobacillus (*At.*) *ferrooxidans*^{T}, *At. ferrooxidans* CF3, *At. ferriphilus*^{T}, *At. ferridurans*^{T}, *Sulfobacillus* (*Sb.*) *thermosulfidooxidans*^{T}



Stage 1
Biomass growth

Stage 2
Bioleaching

Fine tuning

Carried out with **L4** in the following bioleaching conditions:

Experiment A

- 15% (w/v) pulp density
- pH 1.5 and 35°C
- Gassed with OFN
- Inoculated with:

At. ferrooxidans^T, *At. ferrooxidans* CF3, *At. ferriphilus*^{T}, *At. ferridurans*^{T}, *Sb. thermosulfidooxidans*^{T}

Experiment B

- Up to 15% (w/v) in 5% increments
- pH 1.0 and 47°C
- No gas supply
- Inoculated with:

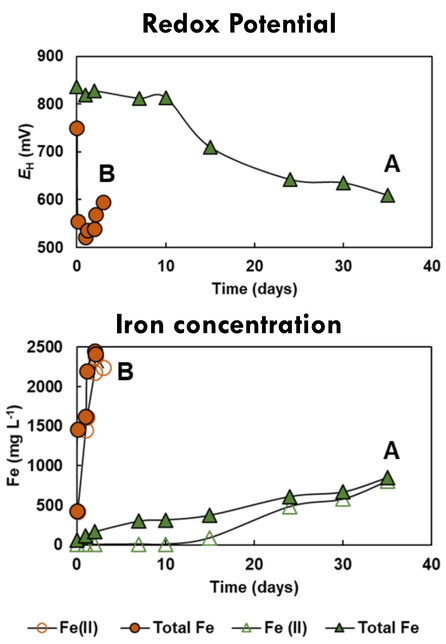
Acidithiomicrobium P2, *At. caldus*, *Sb. acidophilus*, *Sb. thermosulfidooxidans*^{T}

Results

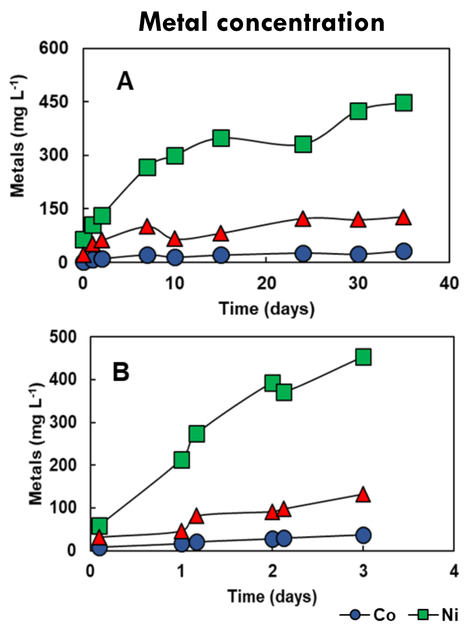
Preliminary screening

Samples	Concentration (ppm)		Recovery (%)	
	Co	Ni	Co	Ni
L1	12	296	41	60
L2	5.5	389	43	54
L3	6.1	337	39	74
L4	10	150	40	37
L5	6.6	188	50	69
NC1*	18	39	41	12

* 10% (w/v)



Fine Tuning



Metal Recovery (%)		
	A	B
Co	53	58
Ni	52	99
Mn	35	20
Fe	4	7
	35 days	3 days

By using the modified technique (Expt. B), over 99% Ni and 58% Co were recovered in only 3 days.

Future work

- Upscaling the process to 10L in laboratory bioreactors
- Development and application of metal precipitation protocol for concentrating Co from leach liquors
- Securing bioleach liquid and solid residues

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