

# The use of heap bioleaching as a pre-treatment for platinum group metal leaching

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**Abstract.** Two samples, a Platreef flotation concentrate and coarse ore (<6 mm), were column bioleached at 65°C using a culture dominated by *Metallosphaera hakonensis*. Based on solution assays, extractions in excess of 90% Cu and Ni were achieved from the flotation concentrate, while from the coarse ore 96% Cu and 67% Ni extractions were achieved. The difference in extraction levels and leaching patterns despite identical conditions used for both samples is discussed, as is the performance of the samples during a follow-up leach step using cyanide to extract the PGMs in a separate column leach experiment. While the recovery of Pd and Au was excellent during these steps, recovery of Pt was limited to 35% after 45 days for the concentrate and 56% after 60 days for the whole ore material, primarily due to the presence of a refractory Pt mineral. Recovery from a concentrate without pre-treatment was substantially lower.

## Introduction

The majority of platinum group metals (PGMs) are recovered from Ni-Cu smelter mattes produced from PGM bearing ores after concentration, and a small quantity is recovered from spent catalysts and copper anode slimes [1]. A critical step in the process is a pressure oxidation leach (in either sulfuric acid or ammonia solution) to leach base metals from the matte, prior to a more aggressive chloride leach to leach the residual PGMs. This approach is not feasible for leaching lower grade and secondary materials. The aim of this study is to investigate the use of heap bioleaching, in a simulated environment, as a pre-treatment to PGM leaching from low grade materials to solubilise base metals and liberate PGM bearing minerals for recovery in a secondary leach step.

## Experimental

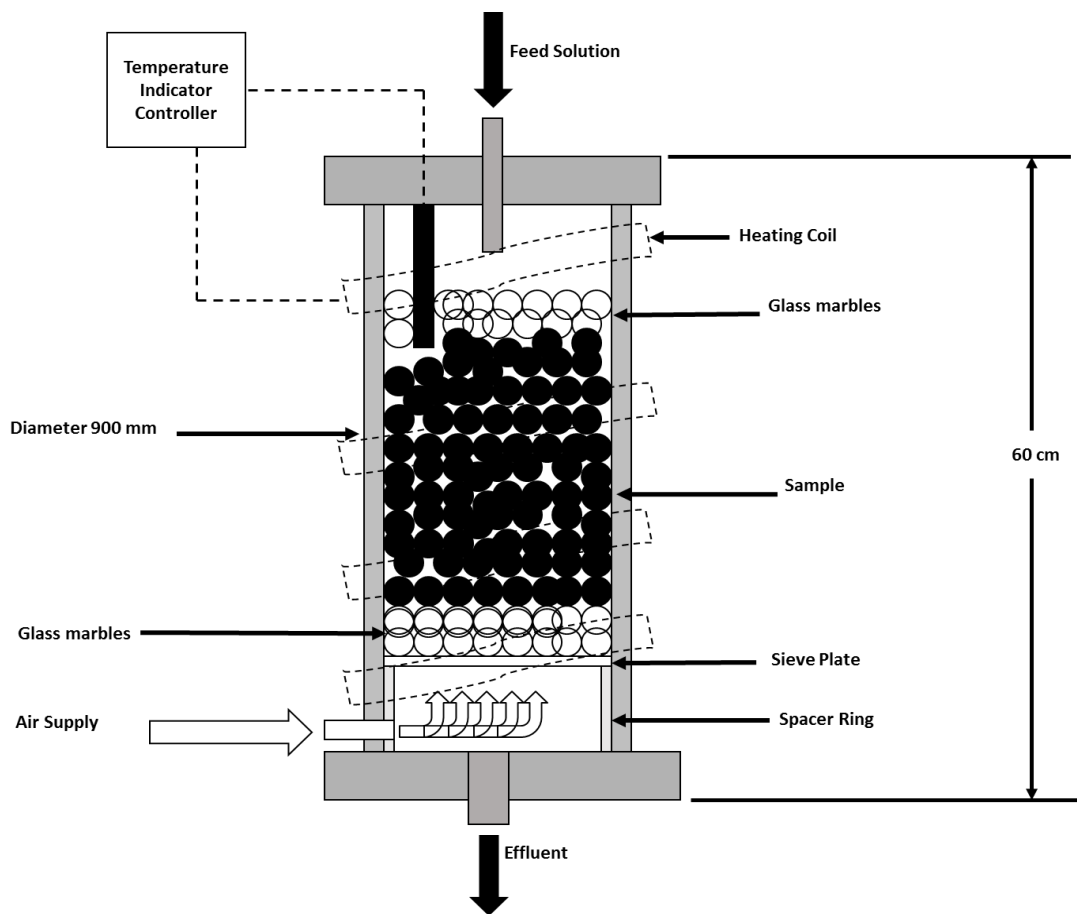
**Materials.** The test samples used originated from Platreef ore obtained from the Bushveld Igneous Complex in South Africa. Sample A was low-grade flotation concentrate (83% passing 38µm) and Sample B was crushed coarse ore screened to a size fraction of -6 mm +1 mm. Analysis via a Mineral Liberation Analyser (MLA) confirmed that Cu and Ni in the concentrate were primarily as chalcopyrite and pentlandite, respectively. Fe was present as pyrite and pyrrhotite with the bulk of the sample being composed of silicate and chromite minerals (Table 1). It was suspected that the coarse ore also originating from the Platreef ore body had a similar mineralogy.

**Method.** Cylindrical columns with heating coils wound around them (Figure 1) were used to simulate thermophilic heap bioleaching. 500 g of the concentrate was made into slurry and coated onto 3.5 kg of granite pebbles, and a sample of 4 kg of the coarse ore was prepared. The two charges were packed into separate columns in between layers of glass marbles that acted as distributors of feed from above and below the column. The columns were fed from the top with a solution made of 10 g/L H<sub>2</sub>SO<sub>4</sub> and

1 g/L  $\text{Fe}^{2+}$  (ferrous sulphate) at a rate of 5 Lhr/m<sup>2</sup>. The columns were aerated at a rate of 1 m<sup>3</sup>hr/m<sup>2</sup> and operated at 65°C.

**Bacterial Culture.** The culture used consisted mostly (99%) of *Metallosphaera hakonensis*, identified and quantified through quantitative real time polymerase chain reaction (qRT PCR) by the Centre for Bioprocess Engineering Research (CeBER) at the University of Cape Town. Within the centre, the culture had previously been used successfully in high temperature Fe oxidation experiments [2].

**Analyses.** Solution samples were taken during the entire duration of the experiments to analyse for base, gangue and precious metals via atomic absorption spectroscopy (AAS). The redox and pH were also monitored using standard laboratory pH and redox probes. On completion of the experiments sub-samples of the residual materials were analysed for S using a sulphur LECO combustion test.



**Figure 1:** Schematic diagram of cylindrical columns used for experiments

**Table 1:** Grades of elements and minerals of importance to study

	Cu	Ni	Co	CuFeS <sub>2</sub>	(Fe,Ni) <sub>9</sub> S <sub>8</sub>	FeS <sub>2</sub>	Fe <sub>(1-x)</sub> S <sub>x</sub>	PGMs 6E <sup>^</sup>
	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[g/t]
<b>A</b>	2.3	3.4	0.1	4.9	7.7	1.9	5.3	55.6
<b>B</b>	0.1	0.4	129 <sup>#</sup>	0.8	1.7	0.1	1.8	4.6

<sup>^</sup>The combined grade of Pt, Pd, Rh, Ru, Ir and Au

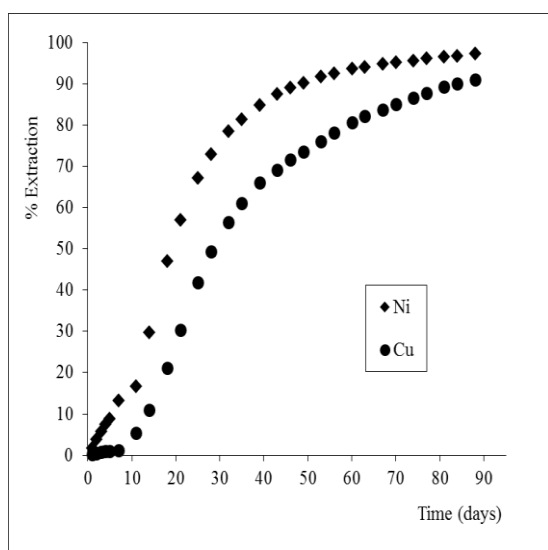
<sup>#</sup>Grade for Co in coarse ore was in g/t

## Results and Discussion

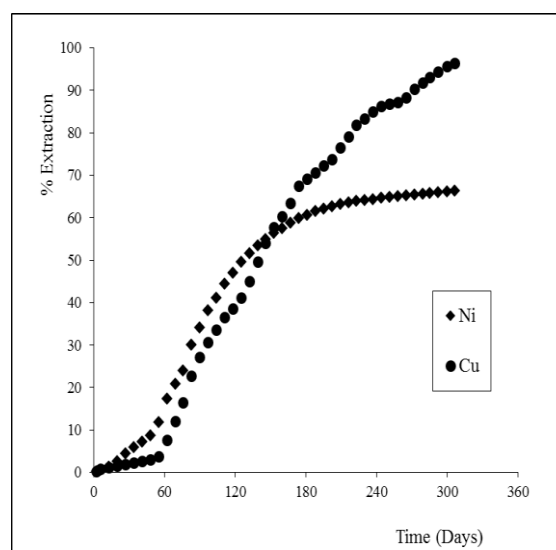
Both the experiments achieved high extractions of the critical base metals Cu and Ni, mostly attributed to the sulphidic nature of the Cu and Ni minerals. A comparison between the two experiments shows that more Ni was leached from the concentrate than from the coarse ore. In the concentrate (Figure 2) the extents to which Ni and Cu are leached are similar. They both seem to initially leach at a similar rate for the first 40 days, although Ni achieves this rate earlier than Cu and hence leaches to a greater extent. Both begin to reduce in rate of extraction at the same time, with Cu dropping slightly quicker than Ni until their final extraction levels. In the case of the coarse ore (Figure 3) again they leach at similar rates with Ni attaining the rate slightly earlier than Cu. After 180 days the Ni levels off while Cu continues to leach. It is suspected that unlike the concentrate perhaps not all the Ni in the coarse ore was in sulphide mineral form.

**Table 2:** Percentage extractions of Cu, Ni, Co and Fe, along with percentage quantity of S oxidised

	Duration [Days]	Cu [%]	Ni [%]	Co [%]	Fe [%]	S [%]
A	88	91	99	88	38	56
B	304	96	67	45	48	75



**Figure 2:** Ni and Cu leach curves for bioleach experiment with flotation concentrate. Fed rate of 5 Lhr/m<sup>2</sup>, 65°C, 1 g/L Fe<sup>2+</sup>, aeration of 1 m<sup>3</sup>hr/m<sup>2</sup>



**Figure 3:** Ni and Cu leach curves for bioleach experiment with coarse ore. Fed rate of 5 Lhr/m<sup>2</sup>, 65°C, 1 g/L Fe<sup>2+</sup>, aeration of 1 m<sup>3</sup>hr/m<sup>2</sup>

In the concentrate experiment a galvanic effect [3] may have been responsible for the faster and higher Ni extraction. The pentlandite in contact with chalcopyrite may have experienced preferential leaching having a lower rest potential and thus acting as an anode with chalcopyrite acting as a cathode. In the coarse ore experiment this effect was absent since there was little or no contact with the mineral grains, as confirmed by MLA analysis. In the concentrate sample the contact between pentlandite and chalcopyrite was facilitated by the fine grinding of the samples, resulting in high surface exposure and hence contact between mineral grains.

The residual materials from the bioleaching experiments were subsequently subjected to secondary cyanide leaching experiments at 50°C using identical columns [4, 5]. The recoveries of Pd and Au were excellent, often exceeding 90%, while recovery of Pt was limited to 35%

after 45 days for the concentrate and 56% after 60 days for the coarse ore material. Further cyanide leaching test work was conducted on the low-grade concentrate using batch stirred tank reactors [4]. The results showed that the Pt recovery from un-treated samples was substantially lower than samples pre-treated with bioleaching or direct acid leaching. The all-around low Pt extractions were ultimately attributed to a cyanide-refractory Pt mineral phase in both the concentrate and the coarse ore.

High pressure liquid chromatography (HPLC) analysis of the cyanide leachate showed high levels of thiocyanate in both experiments. The absence of elemental sulphur in the bioleached materials lead to the conclusion that incomplete sulphur oxidation (Table 2) resulted in the formation of intermediate sulphur species that were highly reactive with the cyanide forming thiocyanate. The use of a mixed culture consisting of both Fe oxidising microorganisms and specialised sulphur oxidising microorganisms would most likely mitigate this problem [6].

## **Conclusion**

Heap bioleaching has shown to be a promising route to further explore at pilot scale for pre-treating low-grade PGM ores for subsequent secondary leaching of precious metals using lixiviants such as cyanide. Extraction of base metals such as Cu, Ni and Co not only removes elements that would otherwise increase cyanide consumption, but also produces commercial value. The use of a mixed culture of both Fe and S oxidising microorganisms is recommended to facilitate complete sulphur oxidation especially in cases where cyanide leaching succeeds bioleaching as the means of PGM extraction.

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