

# MICROORGANISMS ASSISTED DISSOLUTION OF SMELTER AND MATTE-SLAG PRODUCTS

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## Introduction

Oxidised and sulphide cobalt, nickel, copper and zinc bearing minerals are often found in geological formations of the African Copperbelt mineral deposits; and in combination with the accompanying iron oxides and sulphides. Depending on the origin of the deposits often either the straight acid dissolution or the concentration by flotation are conducted prior to the value extraction. In the Zambian part, flotation of the sulfidic ore is followed by smelting of the concentrate in an electric arc furnace; and the matte is further processed downstream. The resulting slag is usually dumped and constitutes now a source of environmental challenges. In the southern Africa, nickel bearing minerals are often found in association with platinum group metals. Optimised flotation plants in Botswana produce a 3.20 %Ni, 0.18%Co and 4%Cu concentrate which is smelted in electric arc furnace before the flash furnace processing. As the Selebi Pikwe mine deposits are deepening further (more the 1000 m underground), the mineralogy of the Run of Mine is then affected. With the same previously set operating conditions for the concentrator and the smelter, important amount of nickel bearing minerals from the matte find their way to the slag when changing mineralogy feed is pumped to the smelter. This paper discusses the findings from value recovery from both the smelter slag from the Copperbelt operations where zinc is trapped and from the matte-slag products from Botswana's operations where nickel value from the matte is entrained into the slag. Selected microorganisms have been used to enhance the recovery of value.

## Experimental

### Materials and Methods

Zambian smelter slag and BCL matte-slag products were used. Slag materials were crushed and milled to pass 75  $\mu\text{m}$  before their characterisation with the X-Rays diffractometer, X-rays fluorescence, Fourier transform infra -red spectrometer and the scanning electron microscopy. The particle size distribution of all materials was

determined while bacteria strains were isolated and grown from South African Johannesburg gold mine water<sup>1</sup>. Dissolution tests were conducted in the laboratory and values concentrations in the leachates were determined using Atomic Absorption Spectrometer.

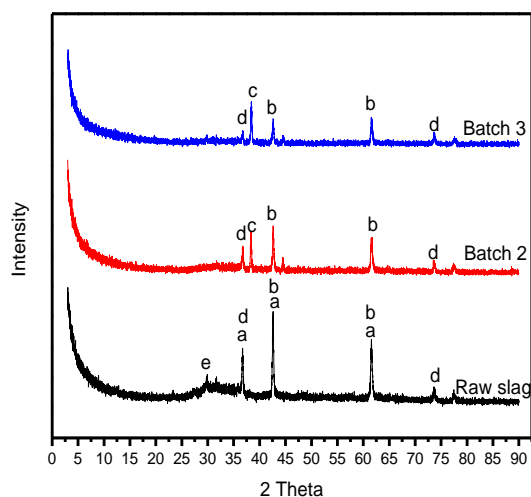
## Results and Discussion

The average composition (table 1) of the smelter slag and that of the matte-slag products show a higher Si/Al ratio for the Southern African Matte-slag product (4.30) than the smelter slag from the copper belt (2.62) indicating that the former is more acidic than the latter. The higher amount of sulphur (2.1%) in the BCL sample (table 1) confirms the presence of the matte in the sample.

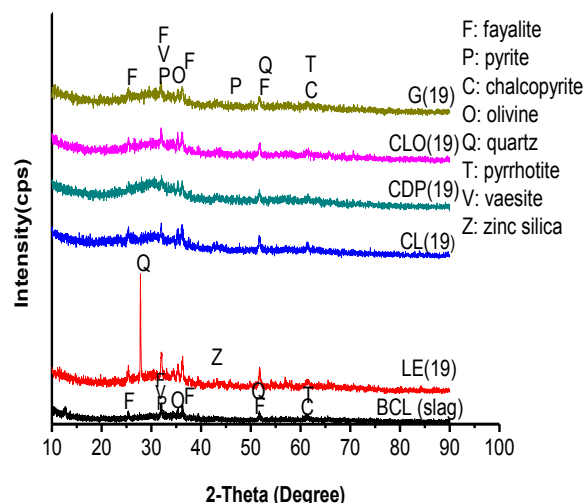
**Table 1:** Chemical composition of the Copperbelt slag and Matte-slag products (%)

|        | Ni   | Cu   | S    | Si    | Fe    | Co   | Zn   | Mg   | Ca    | Al   |
|--------|------|------|------|-------|-------|------|------|------|-------|------|
| Zambia | 0.01 | 0.19 | 0.86 | 7.85  | 26.16 | ---  | 9.00 | 3.01 | 14.08 | 3.00 |
| BCL    | 0.33 | 0.40 | 2.10 | 26.25 | 57.22 | 0.17 | 0.03 | 2.21 | 2.73  | 6.10 |

Figure 2 (a) shows that the as received raw smelter slag is mainly composed of zinc oxide associated with magnesium ferrous oxide, quartz and calcium iron zinc. The smelter slag was leached with the assistance of mixed consortia of bacteria as per<sup>2</sup>. As the dissolution proceeds zinc is removed from the solid as observed by the disappearance of the peak around two theta =36.5 . As the zinc passed into solution, it leaved behind quartz and magnesium ferrous oxide. Leaching with the assistance of *Bacillus Spp*, *lysinibacillus fusiformis*, *Arthrobacter Spp* and *Pseudomonas fluorescens* of the BCL slag gets the slag matrix destroyed (figure 1 (b)). While the major component was Fe<sub>2</sub>SiO<sub>4</sub>, the dissolution brings quartz in solution as seen with the behaviour of peak around 2θ=27.9°. Different pulp densities were tried to ascertain an optimum condition for Zn extraction from the smelter slag when mixed consortia of strains were used. The pulp density of 1% gave a higher Zn recovery of 25 %. Although this is still small with respect to the expected plant conditions, it was the highest among 25% recovery for 1% pulp density and 20% for 2 and 4% pulp density. With the abovementioned bacteria mix, a higher Zn recovery of 30% was observed after 3 days.



**Figure 1(a):** XRD pattern of Zinc bearing slag as leached with consortium of bacteria



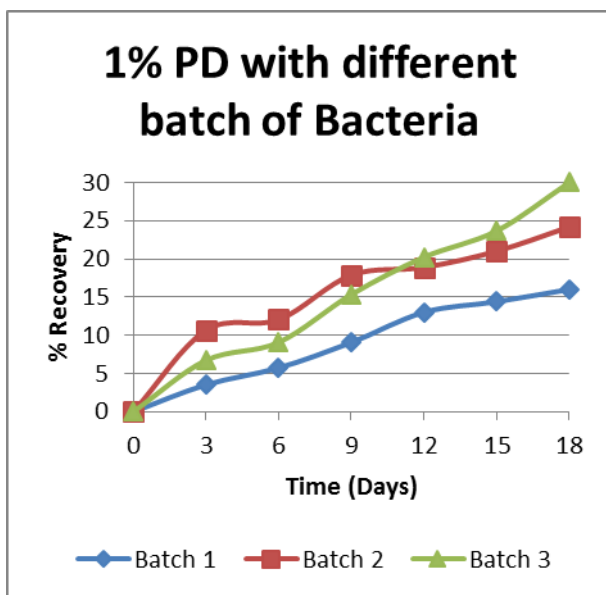
**Figure 1(b):** XRD pattern of matte-slag residue after dissolution with mixed strains.

A different bacteria mix made out of (*Sporosarcana Aquimarana* + *Staphylococcus pasteurii* x 2 with different morphology and *Bacillus*) led to a maximum recovery of 25% while the mix of (*Bacillus* + *Staphylococcus pasteurii* + *Staphylococcus Epidermis* and *Pseudomonas Peli*) showed only a recovery of 15%. On the matte-slag material, *Bacillus spp* were used over a period of 21 days with time intervals of 7 days gap (Figure 2 (b)). As expected<sup>43</sup>, the amount of Ni extracted from the matte-slag product and brought into solution increased with time. At 7 days Cu, Ni and Co were at 11, 10 and 12 % respectively. After 14 days, more than a double of the concentrations was observed in the solution with Co at 25%, Cu at 26% and Ni at 27%. At 21 days Ni was at 26% , Cu at 31% and Co at 34%.

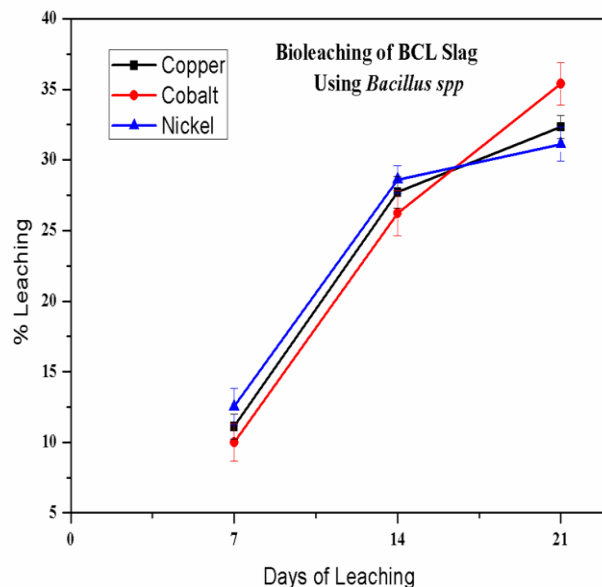
**Table 2:** Zn % recovery with respect to % pulp density

|        | 0 | 3 days | 6 days | 9 days | 12 days | 15 days | 18 days |
|--------|---|--------|--------|--------|---------|---------|---------|
| 1 % PD | 0 | 10     | 12     | 17     | 18.5    | 21      | 25      |
| 2 % PD | 0 | 6      | 5      | 10     | 15      | 15.5    | 20.5    |
| 3 % PD | 0 | 3.5    | 4      | 8      | 12      | 16.5    | 20      |

As expected<sup>4</sup>, it was observed that when the batch 3 mixture of bacteria strains ((*Bacillus* + *Staphylococcus pasteurii* X 2 with different morphology + *Staphylococcus epidermis* + *Sporosarcana Aquimarana* + *Pseudomonas Peli* + *Bacillus*) consortium was used on the Zambia smelter slag, the higher the pulp density, the lower the recovery in function of time (-days) (Table 2).



**Figure 2(a):** Zn recovery from the smelter slag using 3 strains mixes (pulp density 1%).



**Figure 2(b):** *bacillus spp* use in the mixed matte-slag product shows the highest Co dissolution.

A highest zinc recovery of 30% was observed from the smelter slag (Figure 2), while cobalt was noticed to be the metal the more extracted from the matte-slag product. Matte-slag product was leached with four bacterial strains (*Bacillus Spp*, *lysini bacillus fusiformis*, *Arthrobacter Spp* and *Pseudomonas fluorescens*) The tests were conducted over 21 days at a 7 day interval. Results showed optimum recoveries with *Bacillus spp.* as 30% Ni, 32% Cu and 35% Co. Three different organic acids (citric, oxalic and gluconic) at 150 mM concentration and at different temperatures 80, 70 and 60 °C were used to dissolve values from the matte-slag product. At 80 °C citric acid demonstrated after 120 minutes, optimum recoveries of 46% Cu, 46% Ni and 62% Co respectively.

## Conclusion

Bacteria isolated from gold mining aqueous solutions were used for the dissolution of metal values from smelter slag and from matte – slag products. For a given mixture of strains (batch1, batch 2 or batch 3), an increase in pulp density led to a decrease in the zinc recovery from the smelter slag. A 30 % maximum zinc recovery was observed when batch 3 of the mixed species was used. A comparison with sulfuric acid dissolution showed an improved recovery by 5%. *Bacillus spp.* assisted dissolution of Ni, Cu and Co from matte-slag material showed a maximum recovery of 30%, 32% and 35% respectively. A higher selective dissolution of cobalt was observed. The effect of citric acid dissolution was compared with that of oxalic

acid and gluconic acid. It was observed that citric acid value recovery was higher (46% Cu, 46% Ni and 62% Co) at 80 °C for 120 min.

## References

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