

# INVESTIGATION ON THE MECHANISMS OF BIO-PROCESSING VANADIUM SLAGS

**Joelle NTITA, Willie NHETA**

Department of Metallurgy, University of Johannesburg, 2028 Doornfontein, South Africa

*wnheta@uj.ac.za, ntitajoelle@gmail.com*

## Introduction

The Highveld process (South Africa), the New Zealand steel vanadium recovery process (New Zealand), the Pan-steel process (China) and the NTMK duplex process (Russia) are the most common methods used for the recovery of vanadium from V-containing hot metal. Despite the difference of the vanadium containing hot metals and type of reactors, vanadium is oxidised into a vanadium slag by oxygen in all the four process. The Linz-Donawits decarburisation process followed by the pre-oxidation of the hot metal from iron making is the most practised technique<sup>1</sup>.

Extensive research works have been devoted to the recovery of vanadium from vanadium-bearing slags. These include oxidation of molten slag with pure oxygen in the presence of CaO and leaching with sulphuric acid, high pressure oxidation and the well-known alkaline roasting-leaching process<sup>1,2,3</sup>. However, high production costs, complicated processes and the emissions of polluting gases limit further applications of these technologies.

New environmentally friendly process for treatment of low grade ores are compulsory due to the diminution of high grade metal reserves and new strict environmental regulations<sup>4</sup>. Lately, bioleaching has come forth as an efficient technology for the leaching of vanadium either from its slags or ores<sup>5</sup>. The leaching process is carried out by microorganisms such as bacteria and fungi. Examples are *Acidithiobacillus thiooxidans* (autotrophic bacteria), *Pseudomonas putida* (heterotrophic bacteria) and *Aspergillus niger* (fungi)<sup>6</sup>.

Based on previous work done using bacteria, it was demonstrated that during the leaching process, gluconic (Gl), citric (Cit) and oxalic (Ox) acids are generated. The present work is an investigation on a simulation of bioleaching using similar commercial acids on the raw and roasted vanadium bearing slag in order to understand their mutual contribution during the vanadium dissolution.

# Materials and Methods

## Materials

The vanadium slag used in the present study was obtained from Rhovan Glencore Mine based in South Africa and was generated from a steelmaking plant. The chemical composition of the raw and roasted slag was determined using X-ray Fluorescence spectrometer (XRF) Rigaku ZSX Primus II. Identification of mineral phases present in the raw and roasted slag was done using X-ray Diffraction (XRD) Rigaku Ultima IV. The dissolved vanadium from the sample was analysed using atomic absorption spectroscopy (AAS). Reagents used in this experiment were analytical high grade and provided by MERCK.

## Methods

### Roasting and leaching process

The sample was crushed and then pulverised up to 100% passing 75 µm. The pulverised sample was mixed with 10 wt% sodium carbonate. The mixture was pelletised and heated at 800°C for 2 hours in a muffle furnace. The roasted slag was left to cool down inside the furnace for 12 hours. It was then analysed on the XRD to assess the formation of new phases. The raw and roasted slags were then leached separately using gluconic, citric, and oxalic acids at 50, 100, 150 mM concentration. The leaching experiments were carried out at room temperature, 150 rpm of agitation and 2% of solid- liquid ratio. The leached solution was collected for analysis after 20, 100, and 180 minutes. A 250 ml beaker in a shaking water bath was used in the leaching process.

# Results and Discussion

### Characterisation of the raw slag

The chemical composition of the as received sample is shown in Table 1. It can be seen that the slag contains a considerable amount of vanadium (2.57%). Major elements present are aluminium (32.54%) and calcium (13.54%).

**Table 1:** Chemical composition of the slag

Component	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	CaO	V <sub>2</sub> O <sub>5</sub>	Fe <sub>2</sub> O <sub>3</sub>
% Oxide	3.25	7.03	61.49	1.54	18.94	4.58	0.84

The sample was analysed with XRD and the results presented in Figure 1. Vanadium is present in the slag in the form of calcium vanadium oxide (Ca<sub>2</sub>V<sub>2</sub>O<sub>7</sub>) and vanadium oxide (V<sub>2</sub>O<sub>5</sub>). It is also associated with other components such as Fe, Al and Mg in the form of a spinel. Presence of grossite phase (Ca Al<sub>4</sub>O<sub>7</sub>) in the sample was also noticed.

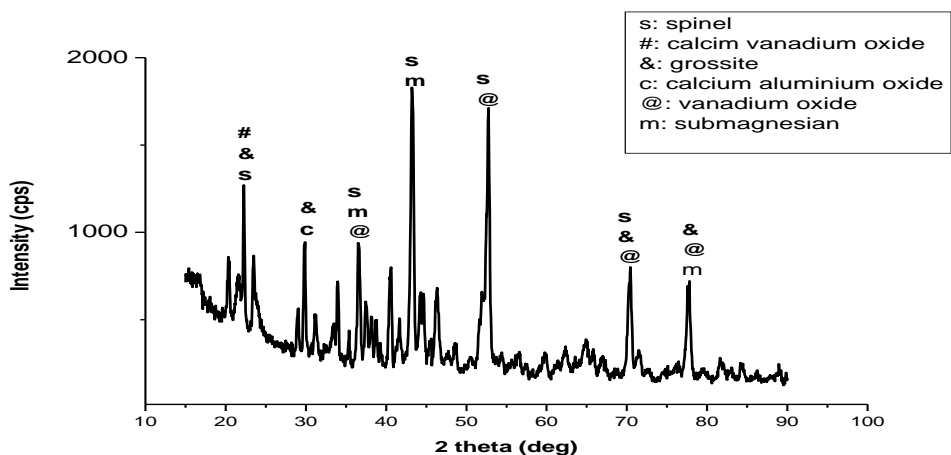


Figure 1: XRD pattern of the V-slag sample

## Leaching experiments

### The effect of acid concentration on the leaching of vanadium from raw and roasted slag

The results on the dissolution of vanadium from the raw and roasted slag while varying the concentration of different acids are given in Figure 2. It can be seen that a maximum of 46.2 ppm (2.5%), 61.2 ppm (3.4%) and 110.73 ppm (6.1%) of vanadium was dissolved while leaching with 150 mM of gluconic, citric and oxalic acids respectively. The dissolution of vanadium is very high on the roasted slag compared to the raw and about 1531.23 ppm, 1121.73 ppm and 1004 ppm were dissolved using Gl, Ci and Ox acid respectively at a concentration of 150 mM.

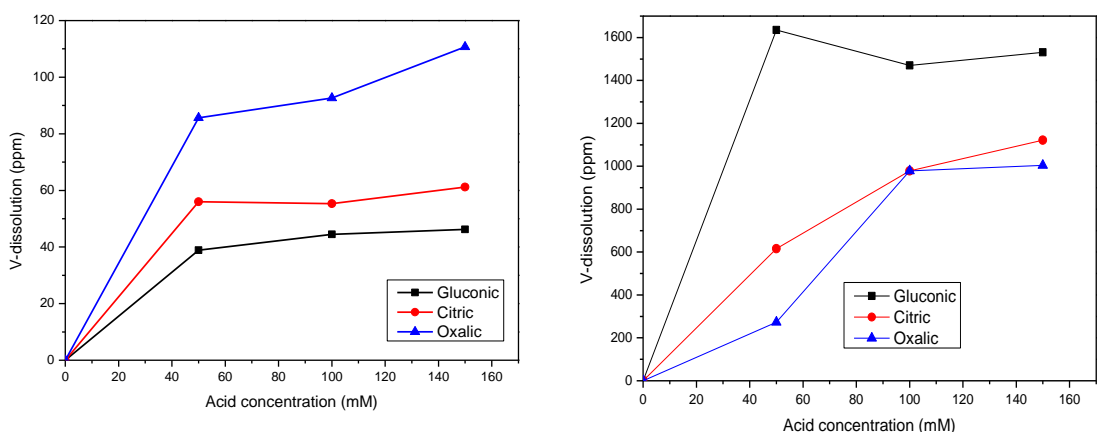
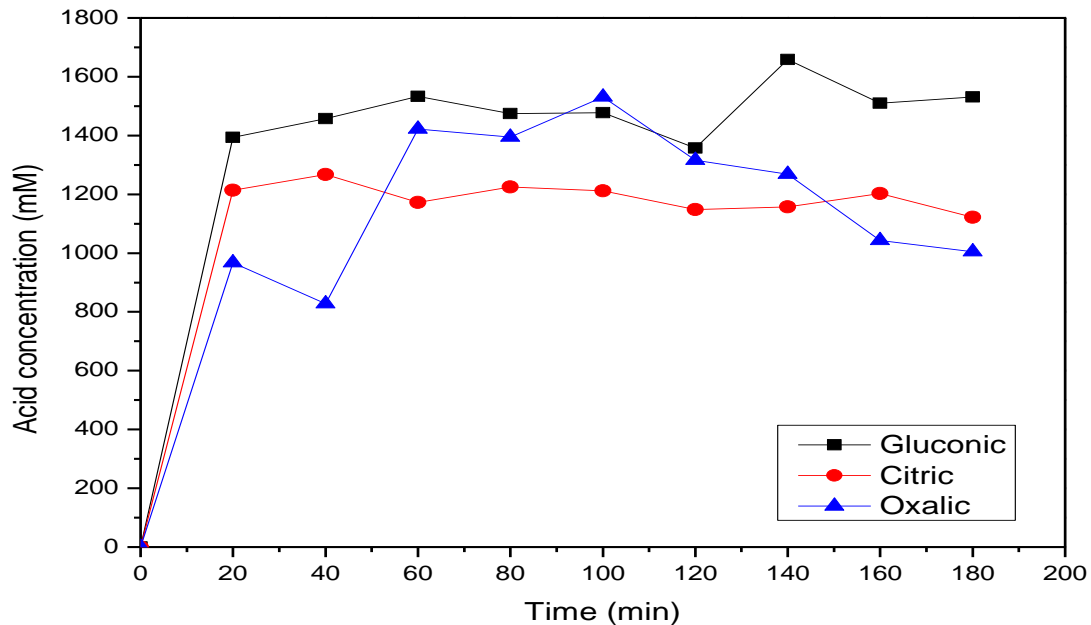


Figure 2: Effect of organic acids concentration on the recovery of vanadium from the raw (left) and roasted slag (right)

### The effect of leaching time on the dissolution of vanadium from roasted slag sample.

The effect of the leaching time on dissolution of vanadium was investigated and the results presented in Figure 3. It was observed that the rate of dissolution in Gl and Ox acids increases with increase in time up to 60 mins. Further increase in time has no

much effect on dissolution in Gl acid but decreases in Ox acid. Leaching time has insignificant effect on dissolution of vanadium in Ci acid.



**Figure 3:** Effect of leaching time on the dissolution of vanadium from the roasted slag

## Conclusions

The leaching experiments indicated that vanadium can be leached from roasted V-bearing slag using very low concentrations of gluconic, oxalic and citric acid. The results suggest that gluconic acid is the best leachate followed by citric acid and then oxalic acid. Optimum leaching time using all acids is 60 mins. Further studies need to target bacteria that produces more of gluconic acid as compared to the other two.

## References

1. G. Zhang, T. Zhang, G. Lü, Y. Zhang, Y. Liu and Z. Liu, "Extraction of Vanadium from Vanadium slag by high pressure oxidative acid leaching", *Int J Min Met Mater*, **21** (22) (2015).
2. X. S. Li, B. Xie, G. E. Wang and X. J. Li, "Oxidation process of low-grade vanadium slag in presence of  $\text{Na}_2\text{CO}_3$ ", *T Nonferr Metal Soc*, **21** (8) 1860–1867 (2011).
3. H. S Chen, "Extraction of vanadium pentoxide from vanadium slag by lime calcination", *Iron Steel Vanadium Titanium*, **13** (6) 1–9 (1992).
4. W. Nheta, T. P. Lubisi, S. Masemola and M. E. Makhatha, "Beneficiation of Haematite from Fluorspar Tailings by reverse Flotation", in *Proceedings of world Congress on Mechanical, Chemical, and Material Engineering*, 346-1 (2015).
5. F. Beolchini, V. Fonti, F. Ferella, M. Centofanti and F. Vegliò, "Bioleaching of Nickel, Vanadium and Molybdenum from Spent Refinery Catalysts", *Adv Mat Res*, **71-73** 657-660 (2009).
6. S. M. J. Mirazimi, Z. Abbasalipour and F. Rashchi, "Vanadium removal from LD converter slag using bacteria and fungi", *J Environ Manage*, **153** 144-151 (2015).