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# KITWE BLACK MOUNTAIN - IS ZAMBIA REALISING THE TRUE VALUE FROM IT?

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## **ABSTRACT**

*Nkana slag dump (The Black Mountain) in Kitwe, Zambia, has existed since 1931 when the copper smelter was commissioned. This 20 million tonnes of smelter slag contains about 0.34 per cent - 4.5 per cent cobalt and average 1.2 per cent copper. When Zambia Consolidated Copper Mines Limited was privatised, the slag dump was purchased by Anglo Vaal Mining (90% shareholding) who built a smelter in Chambishi in 2000 to recover the cobalt and copper in the slag. The smelter operations closed in 2006 and the slag dump was later sold to Nkana Alloy and Smelting Company Limited. Various small scale illegal miners (locally called Jerabos) started illegally reclaiming the slag and selling to Chinese buyers operating small scale mineral processing plants. In the recent past, the government surrendered its 10 per cent shareholding of the slag dump to Chapamo Minerals Processing Company owned by the small scale local community (Jerabos). The substandard technologies being used by these small scale plants yield very low recoveries of about 50-60 per cent for both cobalt and copper, thus discarding huge quantities of valuable cobalt and copper which could be recovered if appropriate technologies were applied. This potential revenue to the nation in taxes is being lost. These small scale plants have not invested in appropriate advanced technology which can yield above 90 per cent recoveries because of their quest to make quick and easy money.*

*The serious safety shortcomings at the slag dump have resulted in unnecessary loss of lives. The recent incident on 21 June, 2018 claimed 11 lives. There is need to study the physical structure of the slag dump to provide clear understanding of the safety precautions to be taken while reclaiming the material.*

*There is, therefore, an opportunity to increase recoveries of the cobalt and copper by applying appropriate advanced technologies to process the slag. This will result in improved revenue, thus realizing the true value.*

**Keywords:** Slag, small scale, cobalt, copper, recoveries

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## INTRODUCTION

The Black Mountain in Kitwe has existed since 1931 when the copper smelter at Nkana mine site was commissioned (Cutler C.J. *et al.*, 2006). This 20 million tonnes of smelter slag contains about 0.34 per cent - 4.5 per cent cobalt and average 1.2 per cent copper (Singh H.P., 2012).

**Figure 1: Nkana Slag Dump (The Black Mountain)**



There are other similar dumps at Mufulira and Luanshya, although these are smaller compared to the Nkana slag dump. The slag dumps on the copperbelt are a result of smelting operations which began in the 1930s. Essentially, the smelting operations involved use of reverberatory furnaces at all the three smelters however, Mufulira smelter adopted the electric furnace as a primary smelting unit in the 1970s and a slag granulation system for easy handling of slag. The slag granulation system was a shift to water cooled slag from the ambient air cooled slag.

The reverberatory furnaces were coal or coal/HFO fired to produce matte and slag. Matte was further processed in the converters to produce blister copper for fire refining in the anode furnaces to produce anodes which were sent to the refineries for electro-refining.

### Slag Composition

The slag chemistry, in all the slag dumps, is very similar as the three smelters treated similar types of concentrates and hence the fluxing of the oxides in the concentrates was very similar. This involved the use of lime rock (calcium carbonate) to attain a low melting and fluid slag with acceptable level of copper loss. In addition to cobalt

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and copper, the feed slag contains about 20 per cent total Fe, 43 per cent SiO<sub>2</sub>, 8 per cent Al<sub>2</sub>O<sub>3</sub>, 8 per cent CaO, 3 per cent MgO, 3 per cent K<sub>2</sub>O, and 0.6 per cent S (Jones R.T. *et al.*, 2001)

It is also important to note that the final handling of the slag has a bearing on the recovery of valuables from it. The ambient-air cooled slag is different from the water granulated one. The latter is quenched fast in water and breaks into fine granules, a process that does not give sufficient time for larger sulphide particles to form thereby making the concentration process better. The ambient-air cooled slag, as is the case for the Nkana and Luanshya slags, results in a better valuable metal recovery, as liberation of metals is attained at a much coarser grind compared to the granulated type.

### **Slag Treatment Processes**

Various slag treatment processes have previously been investigated and some of the methods found suitable have been implemented by various mines globally. Some of the processes are listed below:

#### **a. DC Arc Furnace – Carbothermic Reduction**

Applies reduction of metal oxides using coal or coke at temperatures in excess of 1500°C to recover the metal values. This process was successfully implemented at Chambishi Metals Plc (Singh H.P., 2012).

#### **b. Acid bake**

Slag is backed in sulphuric acid at raised temperatures and thereafter hot water leached (Bulut G, 2006).

#### **c. Flotation**

In Turkey, flotation of slag was investigated and copper recovery of 77 per cent was achieved. Further tests involved roasting the slag tailings with pyrite to recover cobalt (Bulut G. *et al.*, 2007).

#### **d. Leaching**

Oxidative Acid leach involves leaching with sulphuric acid in the presence of ferric sulphate. In other tests hydrogen peroxide was also used (Urosevic, D. Mm *et al.*, May 2014).

Leaching with nitrate, perchloride, hydrochloride, and sulphuric acids, ferric chloride, ferric sulphate, cyanide, SO<sub>2</sub> and ammonia solutions and pressure leaching O<sub>2</sub> processes have also been investigated. Furthermore, the combination of pyrometallurgical processes with leaching has also been investigated. These methods combine roasting using ferrous sulphate, ferric sulphate, pyrite, ammonium sulphate, and sulphuric acid with water leaching (Bulut G, 2006; Sanchez, M. 2004).

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## **PREVIOUS ATTEMPTS TO REPROCESS THE KITWE BLACK MOUNTAIN SLAG**

During periods of high copper prices and insufficient smelter concentrates to fill up the smelters, efforts were made to process the slag through the concentrators to produce the concentrate. Both Nkana and Mufulira concentrators made such efforts and succeeded in producing a smelter concentrate. However, this was done at a great cost due to the abrasive nature of the slag resulting in high grind media consumption and low metal recovery ranging between 50-58 per cent. The moment the copper price dropped on the world market, the process became uneconomical and was discontinued.

There were many attempts made to recover the valuable metal in the slag by leaching methods. These methods worked only in the laboratories and were never commercialised due to the challenges of filtration caused by the formation of the silica gel formed when treating the slag with sulphuric acid.

In the late 1990s, ZCCM shipped thousands of tonnes of slag to Falconbridge, Canada. The slag rich in cobalt sometimes as high as 10 per cent cobalt was treated at the smelter in Sudbury to recover cobalt and copper. The cobalt and copper were recovered at the smelter as matte by processing it in a converter mixed with converter flux. The matte was shipped from Canada to Norway and treated at Christians and metallurgical complex to recover the valuables. Selling of slag generated much needed revenue for ZCCM at the time.

Just prior to privatization, ZCCM undertook a project to recover copper and cobalt from the Nkana black Mountain. Several available methods were looked at and a Carbothermic reduction method was settled for. Due to high energy cost, the process was conceived to be run at Nkana smelter where molten slag at 1200 -1250 degree Centigrade would be charged into a reduction furnace and mixed with the cold slag. This route was deemed viable as there was no need to transport the slag off the plant and heat content of the slag would be balanced with the heat requirement to bring cold slag to reaction temperature.

This project could not proceed as privatisation of ZCCM began, resulting in inter alia sale of Chambishi cobalt plant and the black mountain to Anglo Vaal Mining (Avmin) of South Africa in 1998.

Avmin took up the project of recovering copper and cobalt in the slag and set up a smelter and a hydrometallurgical plant. This involved Carbothermic reduction of the slag in the 40 MW DC arc furnace. The slag was delivered by road from Nkana to Chambishi over a distance of 32km. There was no energy benefit to be obtained from the molten slag arising from primary copper smelting as was originally conceived by ZCCM. The plant was commissioned in January 2001. However, due to low cobalt metal prices and high energy costs, operations became uneconomical and the smelter subsequently closed in 2008. After the closure of the smelter, the black mountain was sold to the Chinese company called Nkana Alloy & Smelting Company Limited, while ZCCM retained their 10 per cent stake.

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**Figure 2: Chambishi Metals 40 MW DC Arc Smelter**



### **CURRENT POSITION**

The current position is that Nkana Alloy and Smelting Company Limited regained its 90 per cent shares while the Government of the Republic of Zambia surrendered its 10 per cent shareholding to Chapamo Minerals Processing Company owned by the small scale miners in local community as a way of empowering them.

This led to the establishment of several Chinese run mineral processing plants within Kitwe, along the Kalulushi Sabina road and other places. These small plants are recovering copper through crushing, milling, tabling and flotation to produce copper concentrates which are mostly sent to the Chambishi Copper Smelter at Chambishi. This initiative by the Chinese nationals is commendable as it has created employment for the Zambian youths who are in dire need of employment. Furthermore, other small industries mainly run by the Chinese supply consumables to these concentrators, also resulted in job creation for the youths.

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**Figure 3: Chinese Concentrator Plant**



There are also some small pyro-metallurgical plants treating the slag and producing copper-iron-cobalt alloys.

Plant trials conducted by Chibuluma Copper Mines concentrator achieved copper recoveries of up to 60 per cent however, this could only be achieved at 50 per cent plant capacity (Sikamo J. *et al.*, 2018).

Luanshya Copper Mines have embarked on treating their smelter slag in a dedicated circuit with Baluba ROM in a separate circuit and have achieved copper recovery ranging between 58-59 per cent for smelter slag at 20-23 per cent copper grade. As is usually the case high grind media consumption remains a challenge.

Optimisation of the country's resources is a very important point to bear in mind when looking at their exploitation. These are wasting assets which will not be there forever. Optimised methods of recovering such assets are critical in order to maximise revenues.

### **CHALLENGES ASSOCIATED WITH THE CURRENT POSITION**

The metal recoveries ranging between 50-60 per cent being obtained at the moment by all the Concentrators are very low compared to other advanced technological processes whose recoveries are above 90 per cent. This is a very wasteful and selfish way of recovering our diminishing limited natural resource. It is further depriving the nation of the much needed revenue in form of taxes. Advanced technologies require adequate investment which the owners of the slag dumps are not willing to take up. They would rather continue with the poor yields to avoid reinvesting their proceeds.

The other challenge created by the current position is the damage to the road infrastructure when transporting the slag to the treatment plants. Roads have depreciated at a very fast rate. The cost for transporting the slag to the treatment plants is high and thus reducing profitability. Furthermore, numerous tailings dumps

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have been created around these plants, resulting in increased ground water pollution and environmental degradation since most of them do not have capacity to set up well designed tailings handling facilities.

### **WAY FORWARD FOR MAXIMUM UTILISATION OF THE SLAG AT NKANA**

Since the current methods used in the treatment of the slag yield very low recoveries, there is a great need to review and adopt better methods in order to ensure that maximum benefit is obtained from the resources.

The DC Arc Furnace –Carbothermic Reduction method previously used at Chambishi Metals is a proven method that yielded very good results. The current owners of the black mountain would benefit greatly if they invested in this technology and the benefits to the nation would be greater. This project would require building the plant within the vicinity of the black mountain. A belt conveyor would then be built to feed the plant. There are many advantages that would be realised such as:

- (i) Higher recoveries would be achieved and thus result in higher benefit to the owners and nation;
- (ii) Transportation costs would be eliminated and damage to the road infrastructure would be minimised;
- (iii) The readily available power and other infrastructure within the vicinity would make it a viable option; and
- (iv) Water pollution and environmental degradation would be avoided.

This would be a much more responsible approach to ensuring that we keep our environment in such a way that posterity will credit us as having had a clever plan for the exploitation of the slag dump. It would make an interesting reading in view of the above to find out what the operating small plants have in their Environmental Impact Assessment reports and what the community reaction was during the reviews.

However, it is also true that wrong decisions could be made in the absence of knowledge or in trying to hide knowledge to other stakeholders or in fact both.

As an alternative, there is a newly reported method of treating smelter slag with metal recoveries above 90 per cent. This method has been suggested by Copperbelt University, Metallurgy Department with a higher metal recovery than what is currently obtaining in these small concentrators. There are also other processing routes that are in use or have been suggested by other researchers.

### **Safety of the Current Operations**

The current operation at the slag dump has shown very serious safety shortcomings resulting in an unnecessary loss of life. The recent incident on 21 June 2018 claimed 11 lives. This is a very sad state of affairs and no such incidents should be allowed to repeat itself.

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There is need to ensure that the safety of the personnel working at the dump is secured. Furthermore, there would be need to secure the area against copper scavengers. Measures should also be put in place to ensure the safety of all persons in close proximity to the site, the residents and property close to the dump.

Understanding the way in which the slag dump was structured and maintained would provide clear understanding of the safety precautions to be taken while reclaiming material. There are still many people on the copperbelt and beyond who worked at Nkana smelter and could provide advice to ensure that safety measures are adhered to.

It must be understood that the slag was dumped at different times and, therefore, the material is compacted in solid mass layers. There were also incidents when emergency dumping pits were made on the slag dump as a contingency measure to improve slag removal rate from furnaces.

**Figure 4: Slag dump area where the recent accident occurred**



## **CONCLUSION**

The substandard technologies being used by the small scale plants yield very low recoveries (50-60%) of both cobalt and copper, thus discarding huge quantities of valuable cobalt and copper which could be recovered if appropriate technologies were applied. This potential revenue to the nation in taxes is being lost. There is, therefore, need for Nkana Alloy and Smelting Company Limited and Chapamo Minerals Processing Company to invest in appropriate advanced technology which can yield higher metal recoveries of above 90 per cent. This will give a higher return on their investment than what they are currently obtaining.



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The spread of small concentrator plants around Kitwe and Kalulushi towns will result in a wide spread of tailings from the slag posing environmental issues to our ground water and unsightly appearance of the land affected. The serious safety shortcomings at the slag dump need to be addressed to avoid further loss of lives. A comprehensive risk assessment of the physical structure of the slag dump should be undertaken to provide a clear understanding of the safety precautions to be taken while reclaiming material.

### ***Disclaimer***

The views expressed in this paper represent those of the authors and NOT the company they work for.

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