IOP Conf. Series: Materials Science and Engineering **391** (2018) 012006 doi:10.1088/1757-899X/391/1/012006

Enhanced Recycling of Waste Copper Smelter Dust from Existing and Proposed Smelter Plant at the Palabora Copper (pty) ltd, impopo, South Africa

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Abstract. The whole facilities at the Palabora Copper (PTY) Ltd (PC), Limpopo, South Africa (i.e. both existing and new) are under obligation to comply with the new plant MES by the 1st of April, 2020. At the moment all processes on the PC mine conform to the MES for existing plant with the exception of the copper smelter and the associated sulphuric acid plant. Despite considerable investment by PC over the last few years in equipment and maintenance, due to the short comings of the copper smelting technology employed on site, certain relevant MES have proven to currently be unachievable. The generation of the waste CSD is considered a global issue and at PC the direct smelting process option is the recycling method currently being used to manage the generated waste CSD at the copper smelting plant. This recycling method is neither cost effective nor energy efficient and it leads to the production of worthless residues. As a result, an enhanced hydrometallurgical based recycling process option is recommended as an appropriate recycling process option. Hence, it was concluded that an industrial scale centrifugal separator like the Knelson or Falcon concentrators be stationed in the existing and proposed plants as a separate but integral part of the ore processing system, so as to reduced/removed the reactive materials it often contains before subjecting it to a hydrometallurgical and Nano technological processing, in order to recover the copper value in it as precipitates of nanoparticles.

Keywords: direct smelting, recycling, waste CSD, hydrometallurgical processing, nano-technological processing

1. Introduction

Palabora Copper (PTY) Ltd (PC), Limpopo, South Africa was issued a provisional Atmospheric Emissions Licence (AEL) with respect to the national environmental management air quality, Acct 39 of 2004 (NEM: AQA) provisional atmospheric emissions license (NEM: AQA) by the Limpopo, provincial department of economicsdevelopment, environment and tourism (LEDET) in April 2015 and is required to meet the minimum emission standards (MES) contained in government notice (GN) R893, promulgated in November 2013in terms of section 21of the NEM: AQA. GN R893 prescribes MES for both existing and new facilities. All facilities (i.e. both existing and new) are required to comply with the new plant MES by

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1st of April, 2020. Currently all processes on the PC mine comply with the MES for existing plant with the exception of the copper smelter and the associated sulphuric acid plant. Despite substantial investment by PC over the last few years in equipment and maintenance, due to the limitations of the out dated copper smelting technology employed on site, certain relevant MES have proven to currently be unachievable. Even though PC is committed to managing its impact on air quality and in order to achieve compliance with relevant MES for new plant at the copper smelter and sulphuric acid plant before 01 April,2020, PC is proposing to implement the smelter Retrofit project. This proposed smelter retrofit project will involves the replacement of the furnace, which will consist amongst other activities a double side blown (DSB) feeding and dust collection system. Howbeit, the actual method to be used in the management of this waste CSD in the dust collecting system of the new plant was not specified in aforementioned report, which invariably leads back to statuesque; the recycling via direct smelting of the dust.
However, the direct smelting process option requires investment in expensive equipment which results in high energy consumption, thus leading to the production of worthless residues [2, 3, 10, 11 and 16]. As a result, an enhanced hydrometallurgical based recycling process option is preferred [12]. In addition, the leach-solvent extraction-electrowinning processing option has been the conventional route of recovering copper from its source as copper cathode slabs [1, 7]. But, recovering the copper value in this waste CSD as precipitates of nano-particles is to be preferred more, owing to vast applications in areas such as heat transfer and microelectronics together with its energy efficiency advantage when compared to electrowinning. A study that has been carried out at laboratory scale [4]; In this instance the authors combined hydrometallurgy with nanotechnology to recover the contained copper in the waste CSD from Iran as nanoparticles of copper oxide (Tenorite). This approach thus illuminates the issues and solutions surrounding the management of the waste CSD from PC.
Hence, this report will start by presenting an overview on the recycling of metallurgical wastes, thereafter the focus will shift to, firstly, ore processing at the existing Palabora copper (PTY) Ltd plant, secondly, ore processing at the proposed Palabora copper (PTY) Ltd plant and finally the proposed enhanced recycling method for the waste CSD at both the existing and proposed Palabora copper (PTY) Ltd plant.

2. An Overview on Recycling and the Waste Copper Smelter Dust

At this moment in time, the disposal of metallurgical wastes such as the waste copper smelter dust (CSD) is becoming costly as a result of increasingly severe environmental code of best practice [8]; in addition, the physical and chemical nature of the waste CSD brands it “hazardous waste” [13]. While in Africa, the South African National Standard (SANS) annual target level of dust is 300 mg/m^2/day and the industrial action level of dust are 1200 mg/m^2/day [14]. Added to this, the national environmental management waste act (Act 59 of 2008) and subsequently the national waste management strategy (NWMS 201) are based on the principles of the waste management hierarchy (Figure 1), which is a framework used worldwide. Recycling in this hierarchy (Figure 1) is one of the important waste management options in order to prevent disposal to the landfill. Despite the recycling industry being in its infancy stage in South Africa, with a need for further development. Hence, emphasis is therefore placed on promoting recycling of waste through the creation of an enabling environment for industry to develop processing facilities as well as educating and assisting other role players, especially the waste producers to also facilitate recycling.

There is one of two basic options to the management of wastes once generated; it is either recycled or disposed. Recycling represents actions that manage in a way, thus resulting in the use of the materials, making it serve as feed for some product or an application distinct from disposal. This is done by segregating waste at source or by extracting materials from it by various techniques, physical, chemical, thermal or biological. Metals and their alloys (steel, aluminum, copper, nickel etc.) are traditionally recycled whereas minerals and products derived from them (e.g. fertilizer, cement) are not recycled. There is growing concern to efficiently manage minerals and the products generated in recovering them from ore bodies. These include waste rocks, tailings, and slags, fly ash and dross.

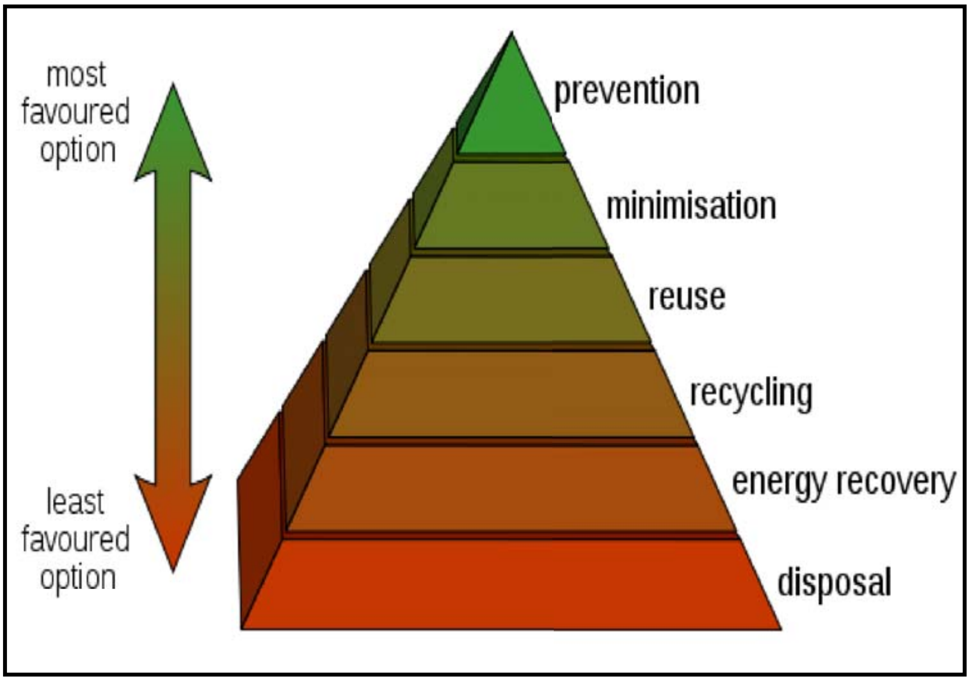


Figure 1: Image showing the waste management hierarchy [5]

Most metals are not consumed (though some of them are subjected to corrosion) and recycling has great environmental and economic pay off.Concentrated scraps, diluted streams and effluent, spent catalysts, arc furnace dust, plating solutions, and process water are some of the examples. Furthermore, recycling is emphasized as it potentially prevents useful material from being combusted or land filled, thus reducing the cost of waste disposal and reducing landfills and tailing ponds. In the metal industry recycling is one of the most effective ways of reducing energy requirement. As metal recycling is done by treating the metal or engineering the material ore, the energy associated with mining the ore is eliminated.

However, waste minimization or ideally elimination of waste is a much sought after objective. What's more technological advances in recent years, together with scientific understanding of the processes that occur, have led to new development towards achieving this goal. It has to be recognized, nevertheless, that recycling continues to be and will remain so for many years to come a major occupation in metallurgical industry for two main reasons. Firstly, metals are a finite source; in industrialized countries, virgin sources of metals natural ores are steadily getting depleted. Recycling of metals from scrap, discarded metal products and engineered materials is an obvious necessity to ensure availability of the metals in desired quantities. Secondly, in many metallurgical processes, nature of reactions is such that products of no direct value for the primary metal industry are inevitably generated. Often considered to be "waste" many of them find their way into landfills or tailings ponds. Furthermore, such waste products have accumulated in huge quantities and call for serious action for resource recovery and environmental reclamation. Resource recovery from such "waste" or converting them to useful by-products is a growing necessity. They will be increasingly in demand to achieve the goal of sustainable development, constant industrial growth for healthy living standards, which requires clean environment and uninterrupted availability of resources.

3. Ore Processing at Existing Palabora Copper (PTY) LTD Plant (EP)

The existing copper smelter is a metallurgical sulphide and converting facility, commissioned in 1966 and comprising of the following:

- A reverberatory furnace (Figure 2A) with dimensions of 36 by 10 m, serving as asmelting furnace with peripheral facility.
- Three Pierce smith converting copper matte into blister copper.
- Three anode furnaces for casting copper into anode for electro refining.
- A sulphuric acid plant with a maximum off-gas treatment capacity of 3,000 normal cubic meters(Nm^3) per minute which fixes SO^2 gas emitted as a waste gas from the converting process, into sulphuric acid.

3.1 Reverberatory Furnace in the EP

Copper concentrate from the mineral processing stage is smelted in the reverberatory (Fig. 2A), converter and anode furnaces, the sulphur content of the concentrate combines with oxygen to release as SO_2, thus purifying the copper. The sulphur to SO_2 ratio is 1: 2 and approximately 75% of the sulphur contained in the copper concentrate is captured during smelting process.

3.2 Electrostatic Precipitator in the EP

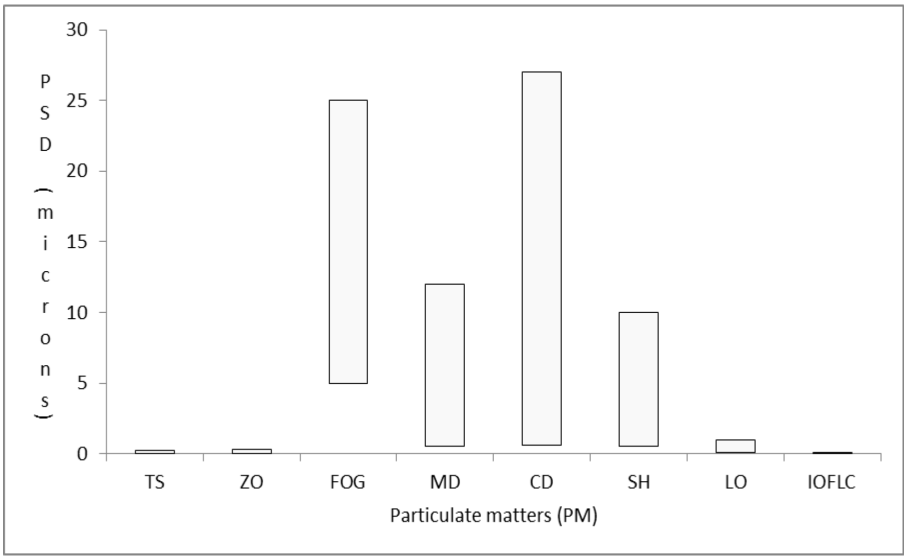
Off-gas from the reverberatory furnace (Fig. 2B) passes through two waste heat boilers and a balloon flue before it reaches a final process of cleaning by electrostatic dust precipitation.The flue dust is returned to the furnace and the low concentration off-gas can be discharged directly into the atmosphere via a 152 meter high concrete stack. It can also be treated in the wet gas scrubbing plant, if the precipitator is off-line. In this instance, once scrubbed, the off-gas is released to the atmosphere via a 70 meter high clean gas stack.The different size ranges for various types of dust, smoke, and fog particle matters and working ranges for different types of gas cleaning equipments are presented on Figure 3 and 4.

3.3 Existing Management Practice of Generated Waste CSD

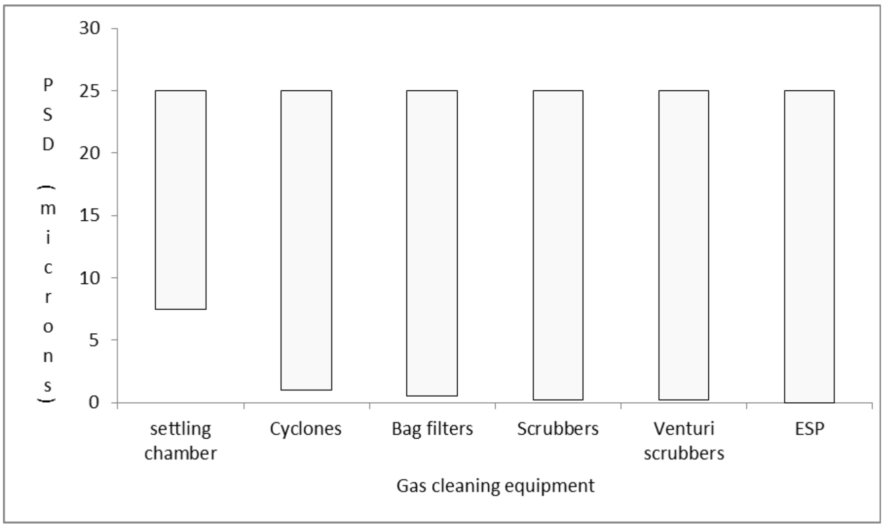
Over the years, PC has embarked on several studies to identify options to sustain and improve environmental performance. Currently all processes on the mine comply with the MES for the existing plant, with the exception of the copper smelter and the associated sulphuric acid plant. Despite substantial investment by PC over the last few years in equipment and maintenance, certain relevant MES have proven to currently be unachievable based on but not limited to the integrated nature of PC's activities, the outdated reverberatory furnace technology, incompatible with the acid plant and associated limited efficiency of the single contact acid plant.

Currently the management practice of waste CSD generated during the smelting of the copper concentrate (Fig. 2B) at the PC is recycling it together with new concentrates as feed. An approach that has been condemned [8]because it requires investment in expensive equipment, results in high energy consumption and thus, leads to the production of worthless residues [2, 3, 10, 11 and 16],and because of its ultra-fine nature (Fig. 3) it causes damage to the refractory bricks of the reverberatory furnace [12].

Figure 2: Images of (A) PC's existing reverberatoy furnace and (B) off-gas from the reverberatory furnace [6].



Key: PSD = Particle size distribution; TS = Tobacco smoke; ZO = Zinc Oxide; MD = metallurgical dust; SH = SO_3-H_2SO_4;
LO = Lead oxide; IOFLC = iron oxide from LD converter; CD = cement dust.
Figure 3: Size range for various types of dust, smoke, and fog [14]



Key: PSD = Particle size distribution; ESP = electrostatic precipitator

Figure 4: Working ranges for different types of gas cleaning equipment [14]

4. Ore Processing at the Proposed Palabora Copper (PTY) ltd Plant

In the proposed new plant (NP) Both the draft basic assessment and environmental management programme report dated October, 2016 and titled: Proposed Smelter Retrofit Project at Palabora Copper was submitted for environmental authorizations in terms of the national environmental management act, 1998 and the national environmental management waste act, 2008 in respect of listed activities that have been triggered by applications in terms of the mineral and petroleum resources development act, 2002 (MPRDA).

5. Proposed Enhanced Recycling of the Waste csd at the Existing and Proposed Palabora Copper (pty) Ltd Plant

A robust data from the physical, chemical, mineralogical and surface morphological characterization of PC's waste CSD has been reported in the open literature [9]. Therein, the authors recommended a mineral processing stage be included in the conventional hydrometallurgical based process options of roast –leach or direct leaching so as topositively impact on the overall processing economy and environment.

6. Conclusion

Based the research conducted and preliminary results presented, it is evident that there is a major gap in knowledge with respect to a mineral processing route and considering the ultra-fine nature (below 53 micron) of the waste CSD, the valuable metal(s) in it can be concentrated using an industrial scale centrifugal separator like the Knelson or Falcon concentrators stationed in the existing and proposed plants as a separate but integral part of the ore processing system. The concentrate which should have reduced/removed reactive materials can subsequently be subjected to hydrometallurgy processing, in order to take its contained copper into solution and further adding value to it by recovering it as precipitates of nano-particles.

Acknowledgement

The authors would wish to thank the Council for scientific and industrial research (CSIR), Pretoria, South Africa andTshwane University of Technology (TUT) for their financial support in the course of this project, while also appreciating PC for providing the waste CSD used for this study.

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