Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 35 (2019) 494–499

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

2nd International Conference on Sustainable Materials Processing and Manufacturing (SMPM 2019)

Waste Management and Treatment of Copper Slag BCL, Selebi Phikwe Botswana: Review

T.S. Gabasiane, S. Bhero, G. Danha*

Botswana International University of Science and Technology, Private Bag 6, Palapye, Botswana 10071
T.S. Gabasiane P. O Box 30105, Botswana

Abstract

The production of copper bears both viable product and by product know as slag which is a challenge to dispose and poses a problem to the environment. BCL holds copper slag is seen as waste which is iron - opulent containing heavy metals which can seep into ground water and affect environment. These metal accumulate in millions of tonnes year after year posing as a threat to the environment and need to be managed to avoid them being harmful. This paper explores metallurgical ways of treating the slag and utilizing it in different ways. Extracting metals such as iron is one way of managing the slag, as previous research and present indicate that iron can be recovered from copper slag. This will help manage the waste slag and rehabilitate land sustainably. The copper slag can also be used in cement and concrete production and provides potential environmental and economic benefits for all parties involved. The BCL dump will be regarded as raw material rather than waste hence igniting management and treatment of waste to sustainability.

Peer-review under responsibility of the organizing committee of SMPM 2019.

Keywords: BCL, Waste Management, Utilization, Slag

* Corresponding author. Tel.:+26772935347; fax: +267 4900102.
E-mail address: tlotlo.gabasiane@studentmail.biust.ac.bw

2351-9789
Peer-review under responsibility of the organizing committee of SMPM 2019.
10.1016/j.promfg.2019.05.071

1. Introduction

The mining industry all over the world produces a whole vast of waste from their production. This paper aims at reviewing Bamangwato Concession Limited (BCL) mine waste (Copper slag) and various ways of managing this waste as well treating it. A large volume of waste is generated at mine sites and their potential for negative environmental impacts, managing waste rock and tailings can be one of the great challenges in responsibly operating a mine. In the past mine wastes were simply dumped in a convenient location which included vacant land, lakes and rivers with little regard for the environment. This practice of uncontrolled dumping of waste is still practiced in some parts of the world with all the environmental regulations in place[1]. Waste produced from mines may include:

- Fumes (Sulfur. Carbon Monoxide, Carbon dioxide)
- Waste water
- Mine dump (copper slag)

Botswana relies on various sectors contributing to its economy but the mining sector in Botswana is evidently the backbone of the country's economy. Agriculture used to be the main sector contributing significantly to the annual GDP in the early periods of Botswana's Independence (1967/68) while the mining contributed 2%. This phenomena changed with time from those early years with the mining sector rising rapidly over the years to date [2]. This phenomena promotes the mining exploration of resources to uphold the economy of Botswana, and hence a lot of Mineral Processing is carried to recover valuable metals from their ores. The Selebi – Phikwe Copper - Nickel Mine was the first large - scale economic enterprise in Botswana by a company known as Bamangwato Concessions Limited (BCL). A series of interlinking processes are used to process the Copper ore, which will produce the core product copper and at the same time produce copper slag which is regarded as waste[3]. This waste was identified to pose negative impacts of mining on natural resources such vegetation, soil, water bodies, land and human population in the area. No environmental mitigation programmes were put in place due no detailed environmental impact assessment was carried out [4].

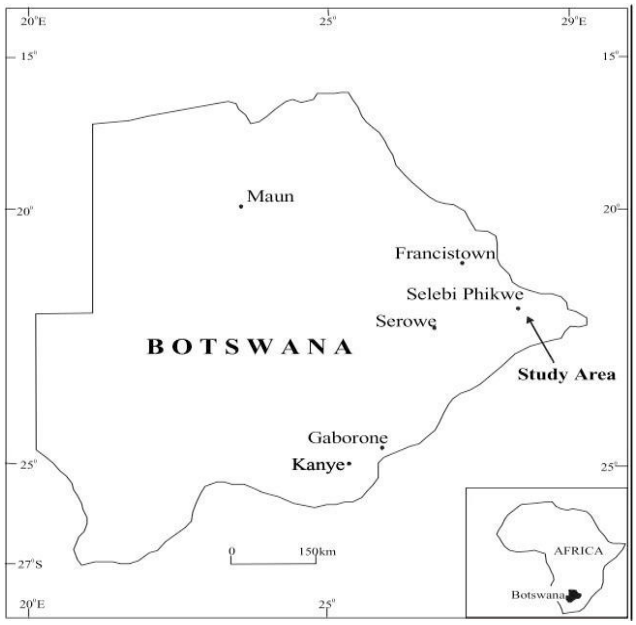

Fig. 1. (a) Botswana Map showing location of Selebi Phikwe

Disposal of slag and dumps from mines and mineral world has proven to be growing problem both environmentally and to the stakeholders, hence it's justifiable to undertake a study on how to tackle this problem which can benefit both parties [2]. The slag dumped just outside the mine poses to be a big issue for the environment as copper slag contains heavy metals associated with copper, nickel, cobalt, iron and lead which can seep to underground water [5]**.**Recovery of metals from dump/slag to profit the plant is considerable cost driver to the process as it will enhance reduction of slag disposal subsequently adding profit to the plant [6]. Disposal of slag is problem and a waste when disposed without recovery of any viable metals from the initial process. Investigation the dump of BCL will be necessary cost – reduction/injection for the plant**.**

Fig. 2. (a) Copper slag

Copper pyro metallurgical slags are inevitable waste by – products of copper smelting operations. This so called waste is considered to be significantly vital due to the high residual metal content that are inadequately recovered during industrial process and due to their high production volume [7]. With that said, over the years copper slag has been disposed in many industrial areas regardless of the weathering and associated environmental risks due to the lack of inadequate practices in the past. A lot of areas where slag has been disposed have shown to be a source of metallic pollution for the surrounding environment. Research and investigations are finding ways of using slag disposed on vacant land outside the mine to benefit all stake holders involved. Some of the uses include cement production, road bed filing and hydraulic construction. Over the years strategies have evolved to modern management strategies which require slags to be evaluated with respect to their environmental stability prior undertaking any reuse action [8].

Treatment and management of Copper slag

2.1 Use of Recycled Copper Slag in Cement - Treated Singapore

Various researched have been exercised to find ways to possibly utilize the copper slag in construction – related applications. Previous research indicate that copper slag exhibits pozzolanic properties which can be used as fractional or full replacement of cement. It is well established that the two major chemical reactions which are induced by the addition of cement and clay and govern the soil cement stabilization process [9]. The process behind this research was based on the primary hydration reaction of cement and water, and reaction of the clay mineral,

$Ca(OH)_2$ and secondary pozzolanic reactions. The initial hydration reaction leads to expansion of strength due to the establishment of main cementations products [9].

The pozzolanic reaction: Silica and alumina react with Ca^{2+} ions, forming calcium silicate hydrate and calcium aluminate hydrate. All these compounds with time will harden and hence improving the strength of the soil cement mixes. If copper slag contains adequate and suitable silica and alumina as well show pozzolanic property this will subsequently aid in pozzolanic reaction and contribute to increase in strength in cement – treated clay. This facilitates that copper slag can be used as partial cement substitute. Utilization of copper slag will aid in managing the waste and subsequently rehabilitation land which was occupied by the slag [9].

Table 1: Chemical composition of copper slag [9]

Element	Column A (*t*)
Si	3.80
Ca	5.21
K	0.76
Fe	38.05
Al	2.75
Mg	0.78
Na	ND
Zn	0.80
Cu	1.02
Cd	ND
Cr	<0.10
Pb	<0.10
As	0.19
Hg	ND

2.2 Characterization of copper slag with view to recover metals

Previous researchers have embarked on various ways to use copper slag to get valuable sources from it hence subsequently using copper slag as a secondary source of valuable materials. Processes have been obtained which are used to get commercial products from slag [5]. Characterization of copper slag has indicated that some valuable metals are present in copper slag, and these metals include, Cobalt (which is one of the expensive metals in the world), iron: is a very important metal in construction, Copper, Nickel. Table one clearly shows the chemical composition of metals present in copper slag associated with nickel and copper [10]. Table 2 shows the chemical compositions of the metals present in amount. This will help map out a process route and flow sheets to obtain the metals.

Table 2: Chemical compositions of typical slag at BCL [5]

Origin	Fe%	S%	CaO%	MgO%	SiO_2	Al_2O_3	Cu%	Co mg/kg	Mn mg/kg	Ni mg/kg	Zn mg/kg
1	44.78	1.06	5.24	1.16	40.97	3.78	-	-	-	-	-
2	39.65	-	3.95	2.82	31.94	2.4	1.01	1040	420	150	7220
3	41.53	0.11	-	-	37.13	-	0.79	-	-	-	-
4	47.80	-	-	-	29.9	-	0.7	-	-	-	-
5	44.7	0.3-0.9	1.6-3.9	-	28.5-32	-	0.5-0.95	Tr -8	-	14-20	1700-2850
6	47.13	1.47	-	-	-	-	0.68	2200	300	500	500
7	44	-	-	-	28	-	0.6	1300	-	600	-
8	47.8	1.5	0.7	1.0	26.1	6.8	0.82	4000	-	-	1500
9	44.8(oxide)	0.28	10.9	1.7	24.7	15.6	2.1	-	4000(oxide)	-	-
10	34.62	0.33	17.42	3.51	27.16	14.7	1.64	-	4900(0xide)	-	-

2.2.1 Incineration of Copper Slag

There are metals which are lost into the copper slag and concentrated over the years and table 2 indicates some of the metals found in the slag which can be extracted and put in use. The deposit from the incineration of waste (slag), favorably fly ash has high amounts of heavy metals and dioxins. It will need further treatment such as vitrification by re – melting / extraction using acid or other solvents [4]. Many products can be recovered from slag after most of their chemical compositions have been altered to safe levels, hence being able to put them to use and sold in different ways which may include:

- Mineral and glass wool
- Slag cement
- Masonry units
- Glass
- Concrete aggregate
- Blasting grit
- Rail ballast[4]

2.2.2 Recover of Cobalt from Slag

The recovery of cobalt would prove feasible from copper slag, hence a lot of research has been carried out in the past especially by Mintek in the early 1988 by a using a DC arc furnace. The process involves maximizing quantity of iron as oxide and selective carbothermic reduction of oxides of cobalt, nickel and copper [4]. This process yielded recoveries of 98% for nickel and over 80% for cobalt from the pilot plant. Process mineralogy studies have revealed that cobalt is present as CoO in copper reverberatory furnace slag and copper in the slag is due to the copper - rich sulphides [7].

2. Conclusion

Copper slag causes many environmental concerns if not attended to hence examining ways to suitably manage and treat copper slag. Reviewing the waste from copper smelting has shown it has many viable ways to utilize the slag after treating it and hence aiding in managing the slag. It has shown that the slag has potential economically after being treated as it bears a lot of viable products which can used and sold in various industries. A lot of metals can be recovered from the slag this makes the slag viable hence can be used up thus aiding to rehabilitate land and used again.

The waste from copper slag can be fully treated and managed with research backing this phenomena to enhance an environmental friendly sector.

3. Acknowledgements

The authors of this review paper would like to thank the Botswana International University of Science and Technology, BCL for supporting this work.

4. References

[1] A. M. W. Primer, "Two Million Tonnes a Day A Mine Waste Primer There are two principal types of solid mine waste: waste rock and tailings .," no. December, 2009.

[2] B. K. Asare and M. B. K. Darkoh, "Socio-Economic and Environmental Impacts of Mining in Botswana: A Case Study of the Selebi-Phikwe Copper-Nickel Mine.," *East. Afr. Soc. Sci. Res. Rev.*, vol. 17, no. January, pp. 1–41, 2001.

[3] N. Tripathi, E. Peek, and M. Stroud, "Advanced process modeling at the BCL smelter: Improving economic and environmental performance," *Jom*, vol. 63, no. 1, pp. 63–67, 2011.

[4] R. T. Jones, "Economic and environmentally beneficial treatment of slags in DC arc furnaces," *Molten slags,fluxes an salts Conf.*, pp. 363–376, 2004.

[5] F. Parada, R. Parra, F. Marquez, R. Jara, J. C. Carrasco, and J. Palacios, "Management of copper pyrometallurgical slags: giving additional value to copper mining industry," *Management*, pp. 543–550, 2004.

[6] H. Li, W. Zhang, J. Wang, Z. Yang, L. Li, and K. Shih, "Copper slag as a catalyst for mercury oxidation in coal combustion flue gas," *Waste Manag.*, vol. 74, pp. 253–259, 2018.

[7] R. T. Jones, G. M. Denton, Q. G. Reynolds, J. A. L. Parker, and G. J. J. van Tonder, "Recovery of cobalt from slag in a DC arc furnace at Chambishi, Zambia," *J. South African Inst. Min. Metall.*, vol. January/Fe, no. FEBRUARY 2002, pp. 5–10, 2002.

[8] D. M. Urosevic, M. D. Dimitrijevic, and Z. D. Jankovic, "Recovery of Copper From Copper Slag and Copper Slag Flotation Tailings," vol. 51, no. 1, 2015.

[9] S. H. Chew and S. K. Bharati, "USE OF RECYCLED COPPER SLAG IN CEMENT-TREATED SINGAPORE MARINE CLAY," pp. 705–706, 2009.

[10] B. Gorai, R. K. Jana, and Premchand, "Characteristics and utilisation of copper slag - A review," *Resour. Conserv. Recycl.*, vol. 39, no. 4, pp. 299–313, 2003.