NorCal Open Access Publications
Journal of Environmental Science and Allied Research
Volume 2017; Issue 01
Ogola JS et al.

Case Study

Possibilities of Reprocessing Tailings Dams for Gold and other Minerals: A Case Study of South Africa

Ogola JS*, Shavhani T and Mundalamo RH

Mining and Environmental Geology, Environmental Sciences, University of Venda, Thohoyandou, South Africa

***Corresponding author:** Jason S Ogola, Mining and Environmental Geology, Environmental Sciences, University of Venda, Thohoyandou, 0950, South Africa, Tel: +27 159628580; +27 768765436; E-mail: ogola@univen.ac.za

Received Date: 20 November, 2017; **Accepted Date:** 17 December, 2017; **Published Date:** 04 January, 2018

Abstract

Steady increase in gold price has led to an era whereby the recovery of gold and other metals from tailings is possible at a profit. 8.3% of South Africa's GDP is from the mining industry and this can be increased by reprocessing gold and other heavy metals that occur within tailings dams. This is particularly promising in South Africa where gold mining started over a hundred years ago at a time where technologies for gold recovery were not advanced. Huge piles of untreated tailings dams have been abandoned whilst others are still being produced all over South Africa, as 40% of gold reserves are found within South Africa. More than 1.7 billion tons of gold tailings dams have been produced in South Africa and they can be refined to produce at least 15 million ounces of gold. Mine wastes are hazardous to the environment and human health. In 1998 of the 418 million tons of hazardous waste that was produced in South Africa, 90% was from the mining industry. Apart from the mine waste being hazardous, it also destroys the aesthetic value of land by disturbing the landscape and consuming land, thus excludes other land users. Previous studies done on different gold tailings dams within South Africa indicated the presence of heavy metals such as Lead (Pb), Arsenic (As), Copper (Cu), Cobalt (Co), Cadmium (Cd), Manganese (Mn) and Nickel (Ni) as well as Gold (Au) and Uranium (U) in varying quantities. The main focus is therefore to determine the amount of these metals in tailings and evaluate their economic viability for reprocessing and getting alternative use for the residue material or relocating waste to more favourable facilities.

Keywords

Environmental and Human Health; Hazardous Waste; Reprocessing of Gold; Tailings Dams

Introduction

In 1998, South Africa produced 418 million tons of hazardous waste and of this, 90% was mine waste, mainly tailings from mineral processing plants. Tailings are fine materials left over after the valuable mineral has been separated from gangue minerals during mineral processing, and is stored in tailings facilities referred to as tailings dams. Tailings form part of mine residues that fall into one of the three categories comprising slime, particle size of about 75% passing 74 μm, sand about 10-20% passing 74 μm, and waste rock [1]. According to these authors, these residue materials constitute a cheap source of gold, especially when exploited as a tonnage make up to fill excess treatment capacity within an existing processing facility. In this scenario, sand or slime can be processed at marginal treatment cost, and can make a substantial contribution to the bottom line profit of an operation. Other benefits to be considered include: release of land for urban development and removal of environmentally unfriendly dumps and their associated long-term liability for relocation to a more modern facility.

Tailings dams if not rehabilitated pose environmental and health problems as they are either blown by wind, dispersing heavy metals into nearby soil and surface water sources or leached by rainwater, contaminating groundwater resources. Chemical reaction of sulphide minerals especially pyrite in the presence of water and oxygen may lead to acid mine water generation that has devastating effect on the environment and human health. The dispersion of these heavy metals to the environment may enter humans through dust inhalation, water resources, dermal contact as well as food chain [2]. Impacts on human health range from respiratory problems to mental disorders. Symptons of heavy metals poisoning such as sensory disturbances, hyporeflexia, tremor, gingivitis, metallic taste, neuroasthenia and night blindness are common [3]. Surface water pollution is generally evidenced by siltation, coloration and acidity. Generally, it is sulphuric acid that gives the strong acidic property, whereas ferrous hydroxide is responsible for the jelly-like orange coloration to water [2]. Sulphuric acid attacks other sulphide minerals, thus breaks them down to release metals such as Lead (Pb), Arsenic (As), Copper (Cu), Zinc (Zn), Cadmium (Cd), Cobalt (Cd), and Nickel (Ni). The stronger the acid solution, the more the metals become soluble in water and this lowers the pH.

Tailings Dam Evaluation

Before any gold tailings dam can be retreated for valuable minerals, evaluation of its residual mineral potential has to be undertaken. This involves drilling and sampling (Figure 1) as well as profile logging, and sample analysis, using such techniques as atomic absorption spectrometry for heavy metals, fire assaying for gold and gamma ray spectrometry for Uranium.

Figure 1: Hand auger drilling and sampling of Fumani tailings dam in Giyani, Province, South Africa.

Sampling and borehole logging are conducted simultaneously. During sampling, physical characteristics such as colour, particle size, texture, hardness and moisture content of the material from the auger bucket are carefully assessed and recorded in the field note book. The depth at which the material is collected is also recorded.

Drilling is generally undertaken from the surface up to the bottom of the tailings facility. All these information is critical for determining the rate of oxidation of tailings in any given tailings facility. Profile logging can indicate the oxidized zone, transitional zone and un-oxidized zone and the thickness of each zone (Figure 2).

Particle size distribution is important for understanding the nature of the dam in terms of its silty and sandy nature. This is more important for identifying alternative use of the residue material, for example, in understanding the geotechnical properties of tailings in construction. Current research shows that gold tailings are composed mainly of silt and sandy materials, hence are not good for bricks making [5]. However, with addition of clay material and coal waste in right proportions good quality bricks can be produced.

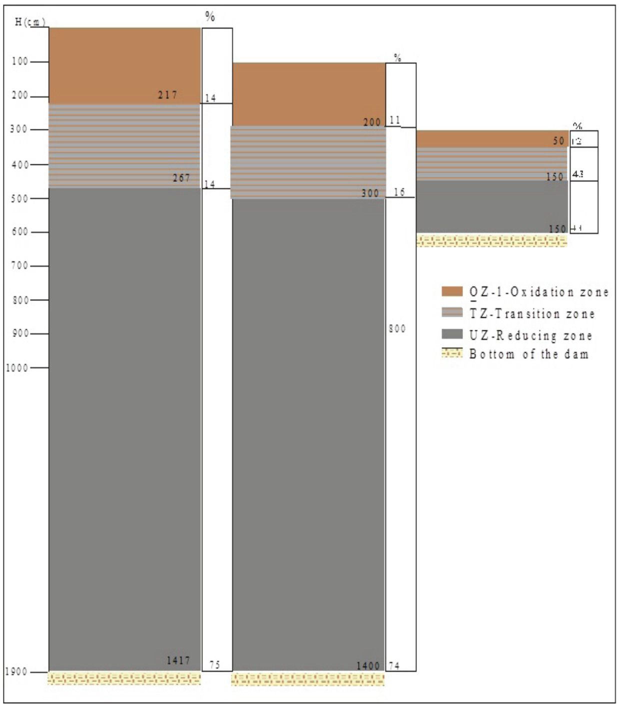

Figure 2: Zones along dam profiles: Oxidized, transitional and un-oxidized zones of the tailings dam at Site B [4].

Moisture content and water retention within the tailings dam determines the extent to which oxidation of the dam takes place. The higher the moisture content, the deeper the oxidation zone of the dam provided that there is enough diffused oxygen. Infiltration of water through tailings material is determined by tailings particle size, distribution and porosity. Well sorted residue deposit leads to high porosity and permeability, provided there is reasonable pore size [6].

The moisture content is also determined by the particle size of tailings. Nengovhela et al., [4] noted that those dams with relatively higher content of clay are better placed to have good water retention potential. They further noted that moisture content within tailings dam is inversely proportional to oxygen concentration, hence development of oxidized zones in the Witwatersrand tailings dams is limited by the amount of oxygen that diffuses through the dam (Figure 3). Yanful [7] had noted that the consumption of pore-gas O_2 through in-situ reactions results in decreasing O_2 concentrations with depth when transport is controlled by the vertical diffusion of O_2 from the atmosphere. This explains why in many tailings dams, the oxidation zone is generally restricted to the first 3-4 m from the surface.

A study of the Klein Letaba gold tailings dam in the Giyani greenstone belt of Limpopo Province, South Africa, revealed the occurrence of heavy metals with varying values (Figure 4). There was abundance of As, Cr, Ni and Mn in the tailings with values of 3943 mg/kg, 759 mg/kg, 731 mg/kg, and 383 mg/kg, respectively. The value Arsenic in the tailings dam was extremely high especially in the northern margin of the dam. However, its distribution within the dam was rather erratic, apparently reflecting

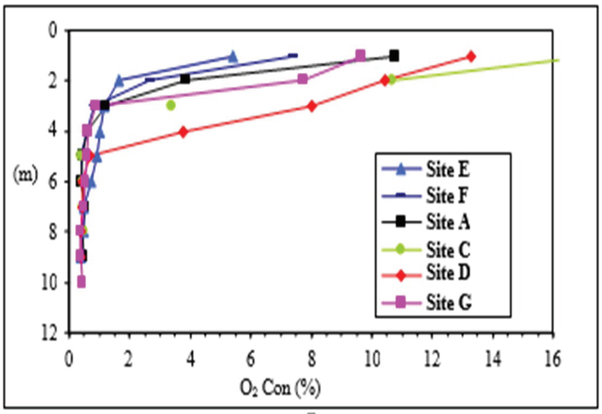

Figure 3: Oxygen readings in the six studied sites with depth from 1 to 10 m [4].

its original distribution within the orebody prior to mining and mineral processing. Gold was observed to have a mean value of 468 µg/kg, and the highest value was 740 µg/kg. The total amount of gold within the tailings dam was found to be 628 kg which at the current gold price in the world market would be about US$ 29 million, although it is technically not possible to extract all of it.

Reprocessing of Tailings Dams in South Africa

In South Africa, there is a long history of gold and uranium mining in the Witwatersrand goldfields. Currently, there are about 6,000 abandoned mines that require government attention and

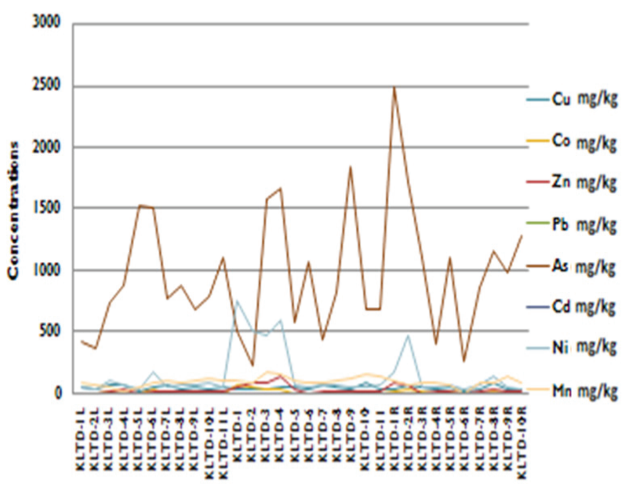

Figure 4: Metal values within the Klein Letaba tailings dam.

the cost of rehabilitating these mine sites is about US$ 2 billion. Consequently, there is need to find alternative means of dealing with mine waste in the country. Surface tailings, arising from mining activities, comprise an estimated 1.7 billion tons of tailings, containing in excess of 15 million oz of gold. Modern metallurgical technology leading to more efficient extraction processes with lower costs and the increase in the price of gold support the extraction of gold from tailings.

Some companies, for example Sibanye Gold Company, have embarked on the retreatment of tailings to extract gold in the West Rand through a project referred to as the Rand Tailings Retreatment Project (WRTRP), which has an eight-year history of extensive metallurgical test work and design (Sibanye Gold Tailings Dams Reprocessing, 2016). The WRTRP aims to recover 11million ounces of gold, 170 million pounds of uranium, as well as sulphuric acid from 1.3 billion tons of tailings. It offers 35 years of mine life, 5,000 construction jobs and 500 sustainable jobs. While extracting valuable minerals from tailings, the company intends to reprocess mine residues in accordance with modern sustainable deposition practices, onto a well-managed Regional Tailings Storage Facility (RTSF) with the return water treated to potable water quality standards. The operations will focus on three main mine sites; the Cooke, Driefontein and Kloof complex. The company intends to treat the first 1.4 million tons a month, recovering about 100,000 oz of gold.

Ergo Gold Reprocessing Company, one of AngloGold Ashanti's five major divisions in South Africa, has been operational for over 25 years in the country. By 2008, it had processed 890 million tons of tailings to produce 8.2 million ounces of gold and 5.5 million pounds of uranium [8].

Currently, the company is a 50/50 joint venture between DRDgold and Australian company Mintails. Outside the joint venture, however, Mintails owns the rights to process and extract gold and uranium from over 305 million tons of slimes, sands and rock tailings materials located in the West Rand. Likewise, DRDgold has extensive surface tailings retreatment operations with its Crown Gold Recoveries division which produced over 100,000 ounces of gold in 2007 [8].

The Ergo Mining joint venture has large mine dumps extending from the Central Rand across the East Rand, containing 1.7 billion tons of material. It has consolidated tailings retreatment on the East Rand. According to the joint venture, operations here could last for 25 years with a yield of about 15 million ounces of gold.

Conclusion

The mine tailings dams in South Africa are currently viewed as a source of alternative supply of gold and other metals, especially uranium as well as a source of sulphuric acid. Recovery of other heavy metals from tailings dams is in the increase, for example silver, hence the need to evaluate heavy minerals in mine tailings dams. Reprocessing of these minerals has been taking place in South Africa for the last 25 years or so. A number of mining companies, for example, Sibenya Gold and AngloGold have acquired the experience and expertise in retreating tailings and mine water to recover gold, uranium and sulphuric acid at a profit. More companies have joined this venture, realizing that there are large deposits of tailings especially within the Witwatersrand Basin. What is required before any treatment of minerals from tailings dam is to undertake evaluation of the mine residue to ascertain the occurrence and quantity of such minerals. A study of the Giyani tailings dams at Klein Letaba has revealed the occurrence and quantity of heavy metals within the dam. The amount of gold within this dam was found to be economically viable. While extracting valuable minerals from tailings, mine residues can be re-deposited onto a well-managed regional tailings storage facility.

Acknowledgement

This paper is based on the work that was taken at the Witwatersrand Basin by Pulles Howard & de Lange (Dr. B.Yibas, Mr. C. Nengovhela and Prof. J.S. Ogola) with the support from Water Research Commission; and NRF and Xstrata SA sponsored projects, undertaken by the Council for Geoscience, University of Venda and the University of Applied Sciences, Ostwestfalen-Lippe, Germany in the Giyani area. All are sincerely acknowledged.

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