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Optimisation of gold recovery from small scale custom mills

Willie Nheta, Mahlori Nkwinika, Moselyn Mailula
University of Johannesburg
Mineral Processing and Technology Research centre
P.O.BOX 17011, Doornfontein 2028, Johannesburg, South Africa
wnheta@uj.ac.za; mahlori1999@gmail.com;

Abstract – Custom mill tailings generated during the treatment of gold ores in Custom milling plants contains a considerable significant amount of gold (Au) and Silver (Ag). The potential of recovering gold and silver from the tailings by cyanidation leaching process was investigated. The custom mill tailings were characterised using Malvern particle analyser, XRF, XRD and SEM-EDs. In this study, the MiniTab software experimental design method was used to determine the optimum leaching conditions. The PSD results revealed that the custom mill tailings are coarse with 80% passing 2000μm. The tailings are a quartzite material containing minor amount of sulphides such as pyrite, chalcopyrite and pentlandite. The amount of these sulphides is very low ruling the probability of the tailings being refractory. Recoveries of 88 and 95% for gold and silver respectively were achieved leaching at 800g/t NaCN 8hrs. However, gold recovery above 85% was achieved by leaching in 600g/t NaCN for 8 hrs. Custom mill tailings have proved to be a source of precious metals and Min Tab software is a useful tool in optimisation of the leaching conditions.

Keywords**:** Gold, small scale mining, artisanal mining, gold leaching, tailings.

1. Introduction

Gold small scale mining (SSM) and artisanal small scale gold mining (ASGM) was treated as illegal mining in many countries for a long time [1]. This led to poor technology development in this area and till today many small scale miners use rudimental equipment. Some countries such as Mozambique, Ghana, Burkina Faso and Zimbabwe has legalised this sector and it is contributing immensely to their total gold production per year. Most of the methods used in SSM/ ASGM mining are gravity concentration methods followed by amalgamation. Amalgamation has been condemned in many countries due to mercury pollution but it has remained the primary method of gold extraction in many developing countries. This is due to the fact that amalgamation is inexpensive but inefficient [2]. This has led to development of extraction methods such as the mercury free small scale gold extraction method [3, 4]. This method involves smelting of gold using borax instead of mercury and about 78% more gold recovery has been claimed [4].

Although the main problem with small scale gold miners is mercury pollution, use of women and child labour, poor recoveries and insufficient knowledge amongst the miners are also major problems [5]. The poor recoveries occur due to inefficient processes that are used prior to the amalgamation or mercury free smelting process. These inefficiencies include poor liberation of the gold particles from the gangue. Generally, hummer mills and wet pans are used for the comminution of the ore prior to gravity concentration process and these produce a coarse product. Though gravity concentration process works well with a course fraction, gold recoveries are usually around 50%. Hence, most of the gold is lost to the tailings. As a results, some of the small scale miners in Mozambique and Zimbabwe have modified the processing circuit by adding leaching processes to the gravity concentration tailings. Still, recoveries in this section are still low due to poor liberation, short residence time, poor aeration and use of incorrect concentrations of sodium cyanide and caustic soda. Apart from that, there is poor understanding of the nature of the gold ores. Some ores are refractory and they need pre-treatment prior to leaching [6, 7].

In this study, characterisation of gold custom mill tailings obtained from one of the ASGM operation was done. The effect of cyanide concentration and leaching time on the gold recovery were investigated and optimised using Mini tab software with the main aim of recovering gold lost to the tailings during gold custom mill operations. Other gold leaching parameters were kept constant.

2. Methodology
2.1 Materials
The gold sample used in the investigation was sourced from one of the ASGM projects in Shamva, Zimbabwe. The tailings from the gold custom mill contained 2.01g/t Au and 1.5g/t Ag. The sample was milled with a rod mill and sieved to have particle size distribution of P80 – 74µm. The results of the X-ray diffraction (XRD) of the sample are shown in Figure 1 and the chemical composition obtained using X-ray fluorescence (XRF) is shown in Table 1. Sodium cyanide at 98% purity and Calcium hydroxide at 95% was used for the leaching experiments.

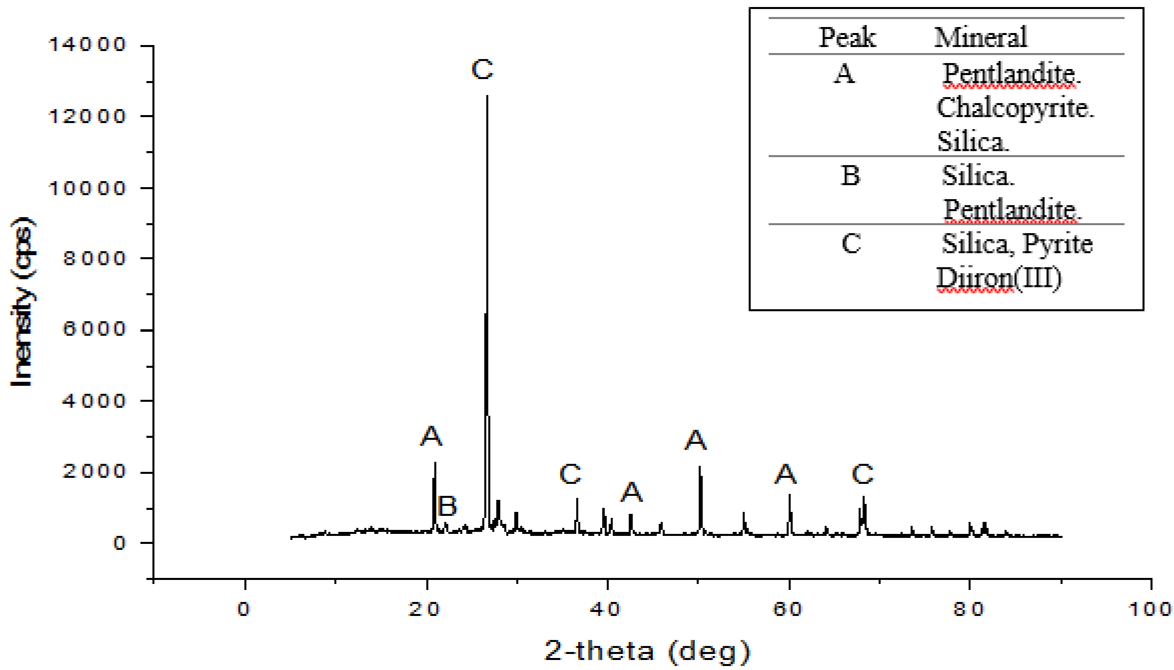

Fig 1: Mineral phases of the of the custom mill gold tailings.

Table 1: Elemental analyses of the custom mill gold tailings.

Element	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr
%wt.	1.4	1.3	9.7	62.4	0.1	0.3	0.1	3.6	3.9	0.9	0.04	0.1
Element	Mn	Fe	Ni	Cu	Zn	As	Rb	Sr	Zr	Ba	Au	Pb
%wt.	0.2	15	0.04	0.07	0.08	0.33	0.02	0.1	0.03	0.11	0.008	0.33

2.2 Leaching experiments
Minitab software was used for the design of experiments focusing on the effect of NaCN concentration and leaching time on gold recovery [8]. The full factorial design matrix for the leaching experiments is shown in Table 1.

Table 2: Full factorial design matrix for the gold leaching experiments.

Leaching experiment	Time (hours)	NaCN dosage (ppm)
1	3	150
2	3	210
3	3	500
4	6	150
5	6	210
6	6	500
7	12	150
8	12	210
9	12	500

A 500g tailings sample with a PSD of 80% passing 74 microns was mixed with water to form a slurry with 50% solids. The pH of the slurry was adjusted to a pH of 11 using Calcium hydroxide and conditioned for ten minutes. NaCN was then added according to conditions shown in Table 1. The leaching experiments were carried out in a water bath as shown in Figure 3 at different leaching time according to Table 1.

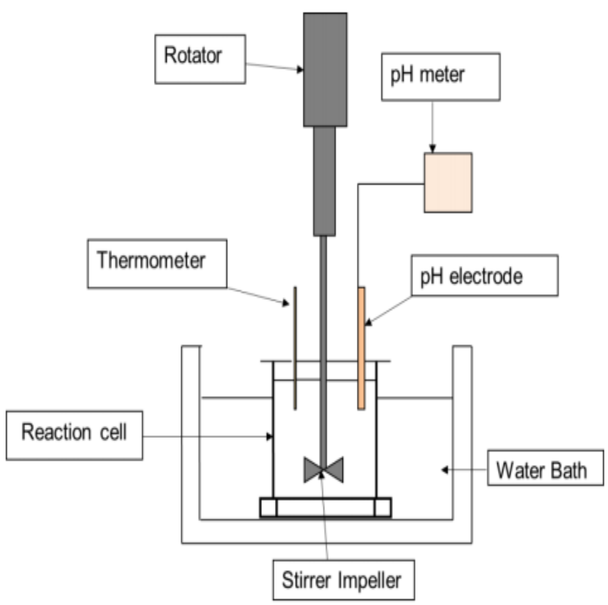

Fig 2: Schematic diagram of equipment set-up for the gold leaching process.

For all the leaching tests the values of the parameters that were kept constant are shown in Table 4.

Table 3: Values of the constant parameters for all the leaching experiments

Parameter	Value
Temperature	25 ^{o}C
pH	11
Stirring rate	900-1000rpm
% solids	50%
Mass of gold sample	500g
Conditioning time before each test	10mins
D_{80}	74 microns

2.3 Analytical Method

The elemental composition of the samples were identified using a Rigaku ZSX Primus II -X-Ray Fluorescence (XRF) machine. The mineralogical phases were identified using the Rigaku Ultima X-ray diffraction (XRD) with Cu Kα radiation. Gold and silver concentration in the solids residue and the head sample were measured using fire assaying and finished by ICP analyses. The morphology of the chromite ore in the samples was analysed using TESCA scanning electron microscope (SEM).

3. Results and Discussion

3.1 Sample characterisation

The particle size distribution of the custom mill tailings was studied using a Malvern particle analyser and the results are shown in Figure 3. Shows that 80% of the material is passing 2000 microns. This shows that the material is still coarse and requires further grinding because the cyanidation method is only applicable for ores, concentrates and tailings having a particle size range less than 200 microns [8].

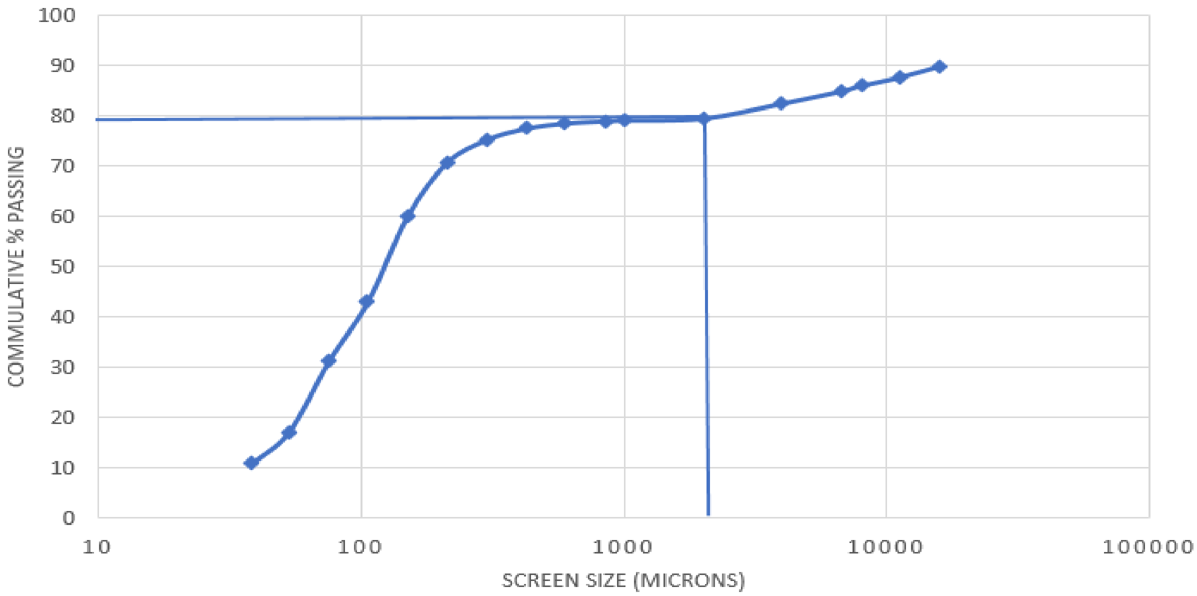

Fig 3: Particle size distribution of the custom mill tailings

The surface topography of the samples was analysed using SEM-EDs and the results are shown in Figure 4. The following phases were revealed *1*- Quartz & chalcopyrite , *2*- arsenopyrite, *3*- pyrite and Titanium oxide, *4* and 5- quartz and *6*-Pyrite.

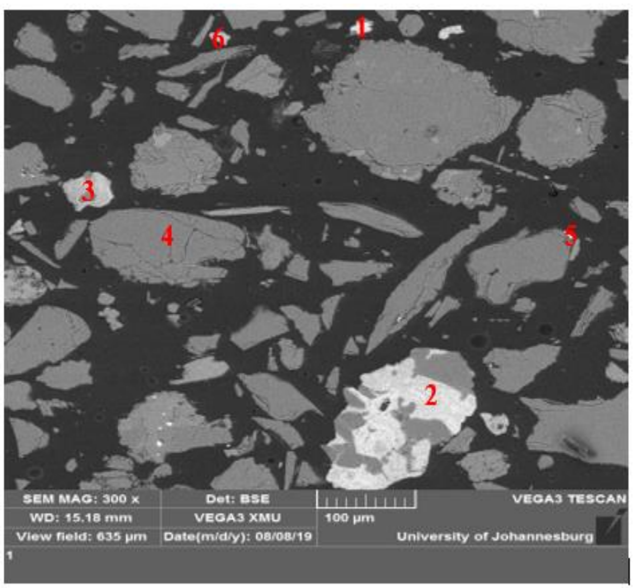

Fig 4: Micrograph of the custom mill tailings

The dominant phase in the tailings was quartz. Minor sulphide phases were revealed but the quantity was very small ruling out the probability of the ore being refractory. Hence, gold and silver recoveries can be increased by liberation and leaching using the correct leaching conditions without any pre-treatment.

3.1 Impact of leaching time and NaCN on gold recovery

The impact of leaching time and NaCN concentration on leaching of gold tailings from a custom mill was assessed using the leaching conditions shown in Table 1 and analysed using Minitab software. The results are shown in Figure 5. Figure 5 illustrates that that Au recovery can be increased from 65 to 95% by increasing the leaching time from 4hrs to 8hrs and increasing the cyanide concentration from 400 to 800g/t. However, recoveries above 85% can be obtained by leaching in 600g/t for 8 hrs.

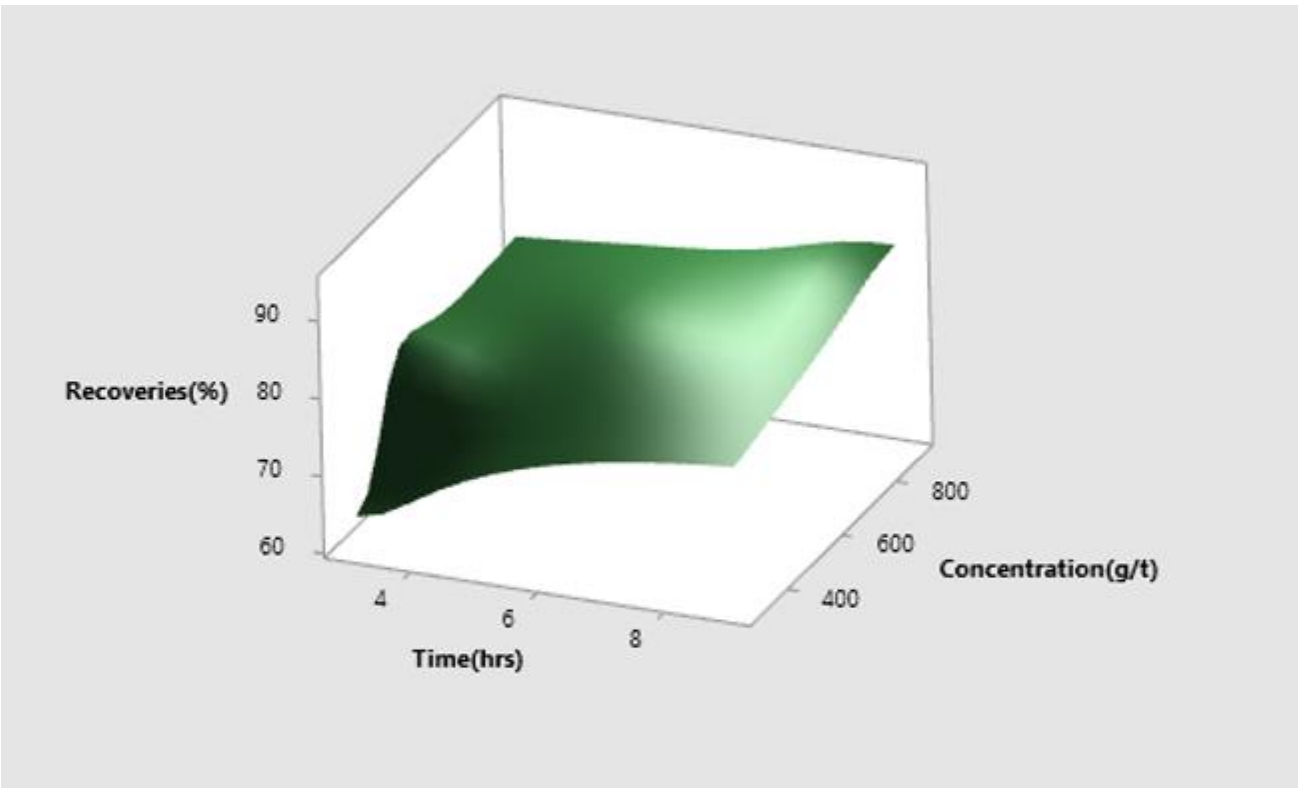

Fig 5: Impact of leaching time and NaCN concentration on gold recovery

The effect of leaching time and NaCN concentration was assessed by leaching the custom mill tailings under the conditions shown in Table 1 and the results are shown in Figure 6. The Silver recovery increased from 63 to 88% by increasing the leaching time from 4 to 8hrs and NaCN concentration from 400 to 800g/t.

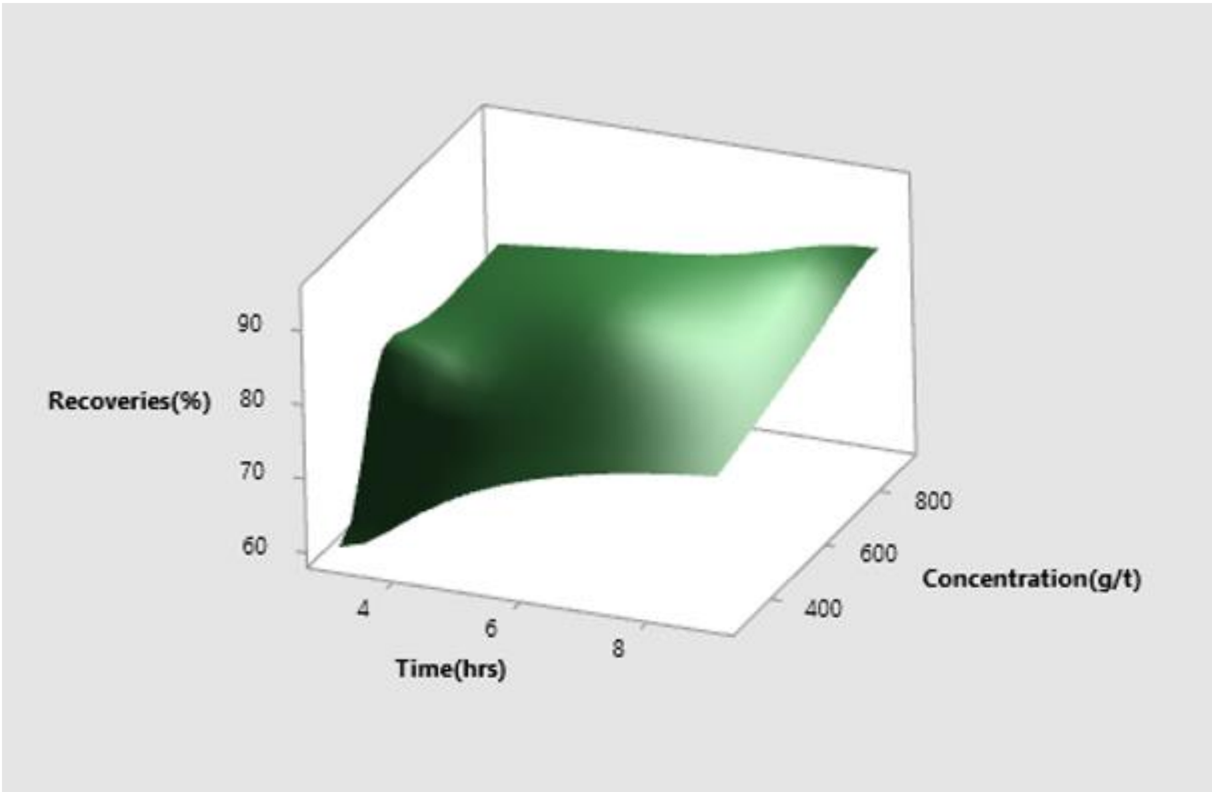

Fig 6: Impact of NaCN concentration and leaching time on silver recovery

4. Conclusion

The present study demonstrated that gold lost in the custom mill tailings can be recovered by cyanidation and the leaching process can be optimised using Minitab software. It has been proved that by reducing the PSD of the custom mill tailings to 80% passing 74µm, controlling the leaching time and the sodium cyanide concentration, silver and gold recoveries can be increased to 88 and 95 % respectively. Custom mill tailings from Shamva area contains 2.01g/t Au and 1.5g/t Ag and it's a potential source of precious metals. It is a quartzite ore and there is no need for pre-treatment of the tailings. Minitab software has proved to a useful tool in optimisation of the leaching conditions and in assessing the interactive effects of the leaching parameters.

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