

## **Geometallurgical Characterization and Processing Gold Ores from Modi Taung Gold Deposit, Yamethin Township, Mandalay Region**

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### **Abstract**

The Modi Taung area is located in central Myanmar, 150 km from southeastern part of Mandalay. The system has been mineralized by silica rich hydrothermal fluids that have created the quartz-Au lode veins which are the deposits main source of gold. Two cyanidation tests were carried out to optimize the mill operations at Modi Taung. The first cyanidation test was done at three different levels of cyanide – 0.03%, 0.06% and 0.09% NaCN. the second cyanidation test was conducted at 0.03% NaCN while adding lead nitrate at concentrations of 0, 25 and 75 g per metric ton of ore. The results confirm that the ore can be easily and rapidly leached and recovered even at low cyanide strength and without lead nitrate addition. Hence it is recommended to lower the cyanide strength being maintained at the mills to 0.03% NaCN and it needs to initially reduce the lead nitrate being added to not more than 25 g/mt of ore. Gradual phasing out of lead nitrate must also be considered especially while the mills are operating at very low pulp density of less than 25% solids.

**Key words:** Cyanidation test, lead nitrate, pulp density, Modi Taung

### **Introduction**

The Modi Taung area is located in central Myanmar, 150 km from southeastern part of Mandalay and 370 km far from north of Yangon (Fig.1). This deposit is an Au-only high grade orogenic gold deposit. The system has been mineralized by silica rich hydrothermal fluids that have created the quartz-Au lode veins which are the deposits main source of gold. Additionally, Au mineralization also occurs within the sedimentary wall rocks, also called host rock, but this mineralization is of a lower grade and only occurs within a metre of to the main lode veins. Gold occurs typically as microscopic disseminated Au in pyrite grains but can also be found as free gold within vugs and cockade texture massive quartz veins in this system.

### **Deposit geology of the study area**

The gold deposit is hosted in the sedimentary units of the Mergui Group, which itself is situated in the eastern extreme of the MMB. The Mergui Group is composed of two dominant sedimentary facies associations. A lower sequence is made up of massive to bedded shale, sandstone, rare limestone and channel fill pebbly wackes (Mitchell et al., 2004). The upper units of the Mergui Group include several polymict conglomerate units which occasionally host marine fossils (Mitchell et al., 2004). In Sinthe area, there are two formations, Kogwe Mudstone and Poklokkale Pebbly Wackestone. The Kogwe Mudstone mainly consists of massive to laminated and locally calcareous mudstone and siltstone interbedded quartzose sandstone which ~~is~~ generally dips to northeast beneath Poklokkale Pebble Wacke. ~~The~~ The lower part of the Kogwe Mudstone includes channel-fill disorganized conglomerates with rafts of mudstones. It passes up transitionally into the Poklokkale Pebbly

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Wacke. This pebbly quartz wackes and pebbly mudstones or diamictites are interbedded with massive and laminated mudstones and siltstones, variably phyllite (Figs. 2 A & B).

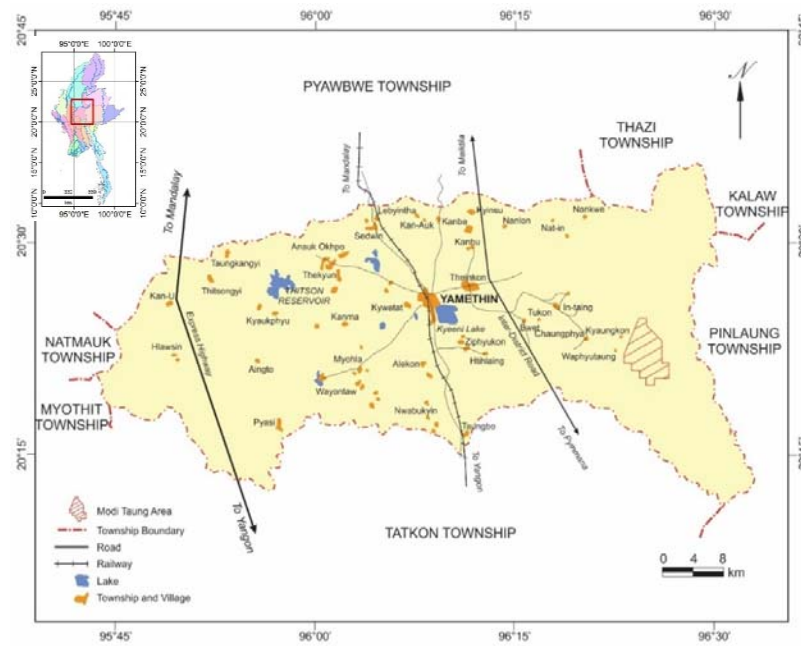


Figure (1). Location map of the Modi Taung area.

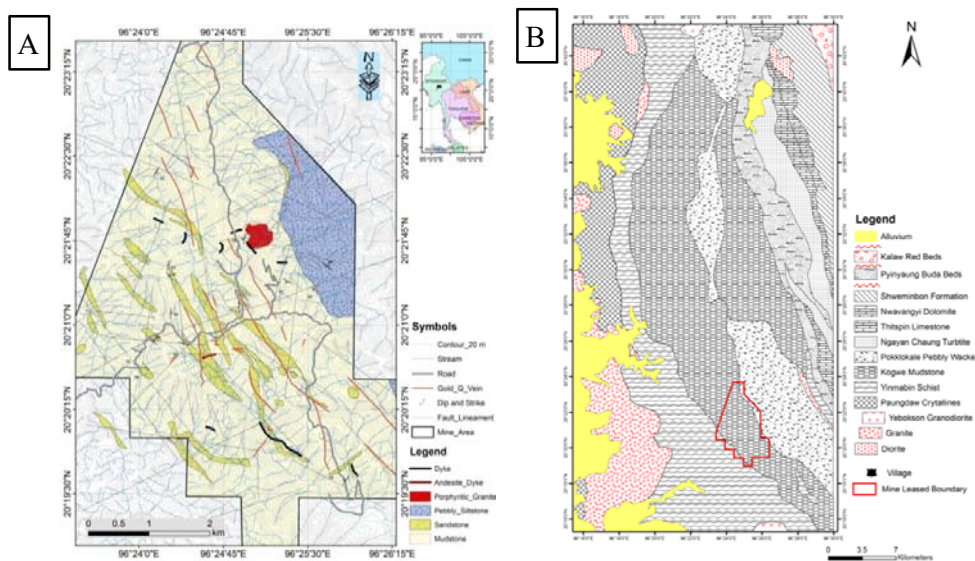


Figure (2). **A.** Geological map of the area. (Source: Mitchell et al., 2004) **B.** Deposit geological map of the area.

### Mineralization

Channel sample across veins in adits has maximum assay up to 300 ppm Au; these high values tend to be in shallower obviously oxidized veins but values up to 100 ppm over 1 m occur beneath the oxidized zone. There is locally extremely variation in assays (3 to 300

ppm Au) across a single vein in channel samples less than a meter apart. Local veins segments with cm-scale parallel bands are containing coarse visible gold implying the existence of ore shoots, but the geometry of, or contours on, possible shoots are so far not known.

In the oxidized zone, which is up to 80 m thick, wall rock alteration is unimpressive, although mudstone ~~silvers-slivers~~ in book-and-ribbon textured veins are weakly or strongly altered to chlorite or chlorite and pyrite. Sandstones adjacent to veins are commonly silicified and sometimes bleached through supergene oxidation of pyrite and ~~consequence-consequent~~ kaolinization, with iron or manganese stains. Beneath the oxidized zone, phyllite within 5 to 10 m of veins shows abundant chlorite together with pyrite on fractures, and sandstones are grey-green, indicating chlorite or sericite and chlorite occurs as selvages on quartz veins. It is uncertain whether the chlorite is ~~similarity-similarly~~ abundant further away from the veins.

### Metallurgical properties for processing

#### Head assay

The head assay portion was pulverized and sent to ALS Minerals (Australia) for analysis prior to proceeding with the test work program, to ensure the grade was typical of the anticipated new plant feed. The results are presented in Table 1. At 5 g/t Au this was considered typical head grade ore. The sulphur (sulphide) assay was also much lower with the main sulphide indicated as pyrite at a theoretical concentration of about 0.7% pyrite.

Table (1). Head assays of the ore samples.

Elements	Units	Results
Gold (Au)	g/t	5.05
Silver (Ag)	g/t	1.6
Arsenic (As)	ppm	40
Copper (Cu)	ppm	22
Iron (Fe)	%	1.47
Lead (Pb)	ppm	107
Sulphur (S)	%	0.38
Zinc (Zn)	ppm	41

#### Cyanidation test on gold ore

Two cyanidation tests were carried out as part of the metallurgical group's effort to optimize the mill operations at Modi Taung. The first cyanidation test was done at three different levels of cyanide – 0.03%, 0.06% and 0.09% NaCN. It was done to evaluate the behavior of the ore and other operational parameters. Specifically, the following were the objectives of the test work:

1. Evaluate the ease by which the gold can be leached, that is, examine leaching and adsorption time as well as the gold recovery at different cyanide levels
2. Determine cyanide consumption
3. Determine lime consumption

After determining in the first test that the ore can easily be leached at lower levels of NaCN, the second cyanidation test was conducted at 0.03% NaCN while adding lead nitrate at concentrations of 0, 25 and 75 g per metric ton of ore. The objective is to determine the effect of lead nitrate on the rate of leaching and Au recovery. The second test will also serve as confirmatory test of the results of the first test. In addition, the amount of activated carbon was also increased from 25 g to 30 g in the second test to check if this will result in lower Au losses in the tails solution.

### Sample preparation

Approximately 25 kilograms of (0.5" - 1") crushed sample was obtained from the ore stockpile. The ore was further crushed to <0.25" in the laboratory before reducing the sample size 12 kilograms by coning and quartering.

Grinding to 80% passing 200 mesh. To determine the time required to pulverize the ore to 80% passing 200 mesh, four 500-kilogram portions were taken and pulverized at 1.5, 2.0, 2.5 and 3.0 minutes. The pulverized ores were then wet screened using a 200-mesh screen. The resulting % passing (Fig. 3) was then extrapolated to determine the desired pulverizing time of 2.28 minutes. The rest of the samples were then pulverized for 2 minutes and 15 seconds.

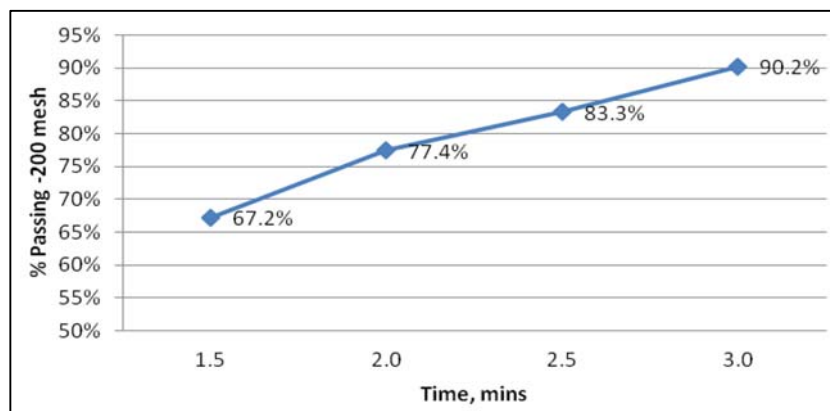


Figure (3). The resulting % passing was then extrapolated to determine the desired pulverizing time.

Six 900-gram samples were taken for the cyanidation test. A 100-g sample was obtained from each of the 6 samples and consolidated for head assay analysis.

Three (3) samples were used for the first cyanidation to determine the optimum cyanide strength. The remaining 3 samples are then used for the second cyanidation test, which aimed to check the effect of lead nitrate addition as well as a confirmatory test for the results of the first test.

### Cyanidation test procedure

Below is the summary of procedure used for the cyanidation test. Three 800-kg ore samples were placed in Winchester bottles; 1,200 ml water was added to achieve a 40% pulp density.

- Cyanide was added to get 0.03%, 0.06% and 0.09% NaCN, respectively; additional cyanide was added to maintain these cyanide levels
- Lime was also added to raise the pH to 10.5 – 11. However, after adding only 1 g of lime, the pH of the samples rose to pH 11.2 – 11.5 already
- The bottles were then placed in the bottle roller for continuous agitation
- The pH, % NaCN and gold recovery at 2, 4, 8, 16, 24, 32 and 40 hours
- 25-g each of activated carbon was then added at 24 hrs
- After 40 hours, the loaded carbon was screened from the slurry; the slurry (tails) was then filtered to separate the barren leach solution and the solid residue. The carbon, barren leach solution and residue were all assayed for Au content.

The above procedure was repeated on the next batch to test the effect of lead nitrate addition. The only difference is that the cyanide strength maintained for all three bottles were the same at 0.03% NaCN, while adding 0 g, 0.02 g and 0.06 g of lead nitrate for bottles 1, 2 and 3, respectively (or 0, 25 and 75 g lead nitrate per mt ore). The activated carbon added at 24 hours was also increased to 30 grams each to check if this will result to lower Au content in the tailings solution.

## Results and findings

The summary of parameters maintained and results for the two batches of cyanidation tests are tabulated below:

Table (2). Summary of cyanidation test parameters and results.

Parameters	Units	S-1	S-2	S-3	S-4	S-5	S-6
<u>Test parameters maintained</u>							
NaCN strength maintained	%	0.03%	0.06%	0.09%	0.03%	0.03%	0.03%
Lead nitrate added	g				0.06	0.02	0.00
Pulp density	%	40%	40%	40%	40%	40%	40%
Weight of ore	g	800	800	800	800	800	800
Volume of solution	ml	1,200	1,200	1,200	1,200	1,200	1,200
Activated carbon added	g	25	25	25	30	30	30
<u>Au leaching and recovery</u>							
Composite head assay	ppm	20.11	20.11	20.11	20.11	20.11	20.11
Au recovery							
@ 2 hours	%	59.8	75.1	71.4	48.4	52.6	42.6
@ 4 hours	%	75.2	89.6	92.0	74.3	77.4	73.6
@ 8 hours	%	96.8	98.8	100.2	91.5	87.8	89.8
@ 16 hours	%	106.6	103.0	82.9	99.0	97.7	98.3
@ 24 hours	%	97.9	107.5	104.4			
Final Au recovery	%	98.5	97.5	97.9			

Au in tails, dry solids	ppm	0.295	0.368	0.346			
Au in tails, solution	ppm	0.03	0.02	0.02			
Au in carbon	ppm	704.505	503.333	563.216			
Calculated head assay	ppm	20.76	15.96	16.88			
<b>pH and Reagent consumption</b>							
Cyanide consumption	kg/mt ore	0.59	1.06	1.6	0.689	0.697	0.698
Lime consumption	kg/mt ore	1.3	1.3	1.3	2.4	2.4	2.4
Initial pH (w/o lime)		8.8	8.8	8.8	8.6	8.6	8.6
Initial pH		11.2	11.3	11.5	10.5	10.5	10.5
Final pH		10.3	10.7	10.7	10.2	10.2	10.2

### **Cyanidation test with NaCN solution**

#### Leaching rate and gold recovery

- Leaching of the ore is rapid; at 8 hours, at 96% of the gold were already leached. Leaching is already complete by 16 hours (see Table 2 and Fig. 4).
- Leaching is faster for samples 2 and 3 (0.06% and 0.09% NaCN) than for sample 1 (0.03% NaCN); but final Au recovery is practically the same (97.5% to 98.5%) for all samples
- Gold in tailings residue is very low at 0.295, 0.368 and 0.346 ppm for samples 1 to 3, respectively
- Gold in tailings solution is also acceptable at 0.02-0.03 ppm

#### Cyanide and lime consumption

- Decrease in cyanide strength is very little throughout the test and as a result, cyanide consumption is very low at 0.6, 1.1 and 1.6 kg/mt for samples 1 to 3, respectively (Figure 5).
- The pH of the ore before lime addition is already basic at pH 8.8; hence, the pH reached pH 11.2 to 11.5 already after only adding 1 g of lime. The pH decreased to 10.3 to 10.7 at the end of the test, so additional lime was no longer added. Lime consumption is also very low at only 1.3 kg/mt ore.

#### Analytical errors

- The calculated head assay for samples 2 and 3 is 15.96 and 16.88 ppm; this is considerably lower than the head assay of 20.11 pointing to possible procedural errors resulting to Au losses
- Instead of consistently trending upward, gold recovery fluctuates (especially when it approached 100% Au recovery) and sometimes exceed 100% Au recovery; this points to possible assaying (AAS) test errors

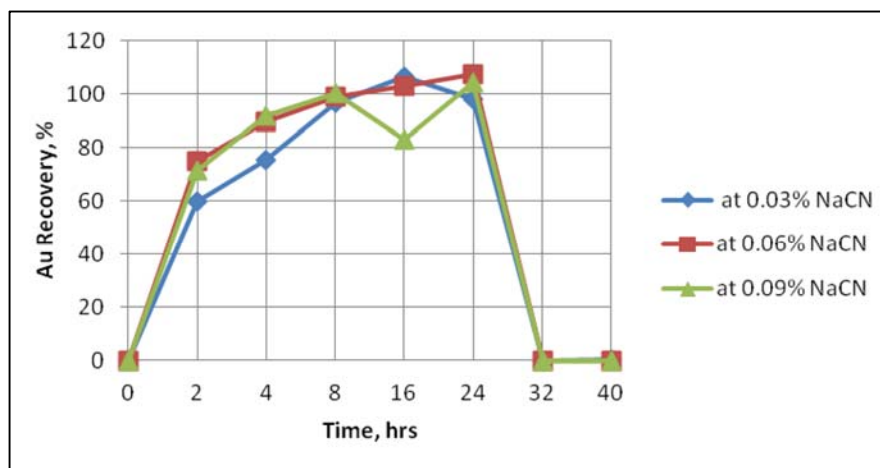


Figure (4). Leaching of the ore of Au recovery vs. leaching time with NaCN testing.

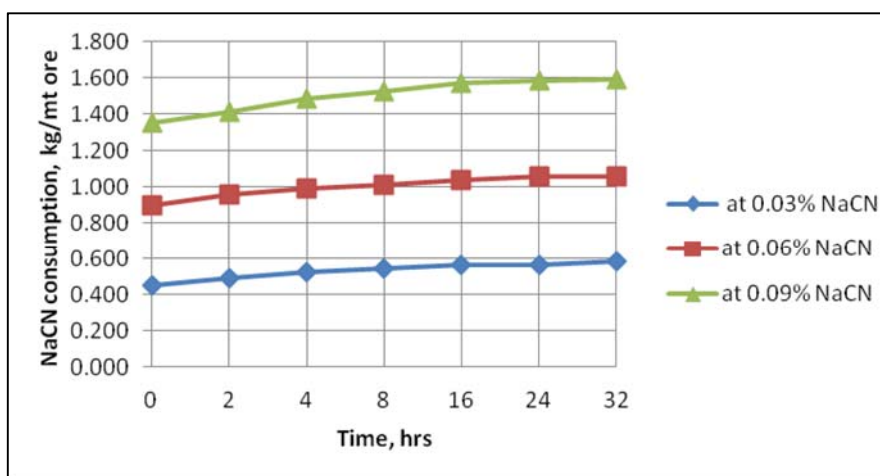


Figure (5). NaCN consumption vs. time of the ore.

### Cyanidation test with lead nitrate solution

#### Leaching rate and gold recovery

- There is practically no difference between the leaching and recovery rates of the samples with or without lead nitrate (Figure 6). This is expected since, as noted in the first batch of test, leaching is already very rapid without the lead nitrate. Hence, adding lead nitrate no longer provides material benefit to the process. By the 16<sup>th</sup> hour, at least 97% of Au have already been dissolved.

#### Cyanide and lime consumption

- Similar to the first test, cyanide consumption is also very low at 0.69-0.7 kg NaCN/mt of ore (Figure 7).
- For some reason, the lime consumption is significantly higher than in the first test. This may be due to the water being used in the experiment even though the water used for both tests are 'distilled'.

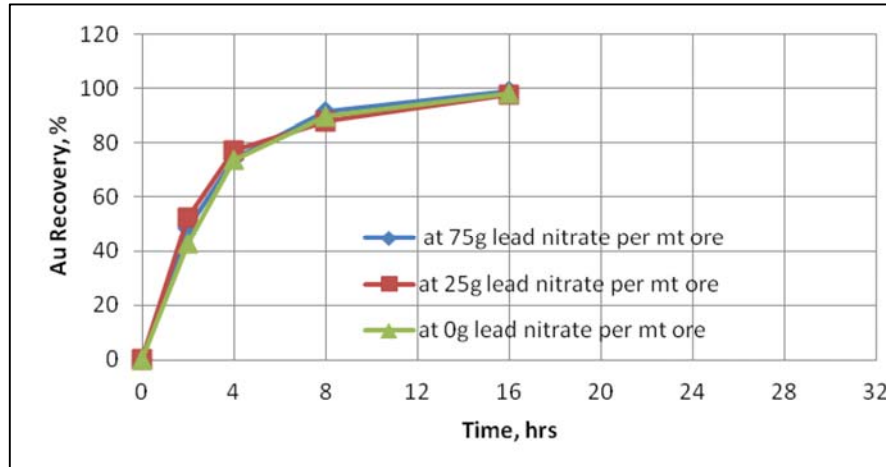


Figure (6). Au recovery vs. time with lead nitrate testing.

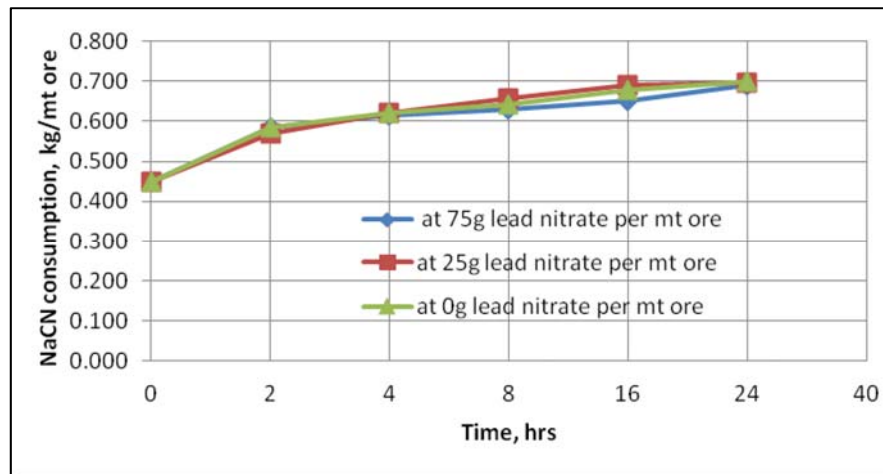


Figure (7). NaCN consumption vs. time with lead nitrate.

## Processing procedure

### Grinding and sizing

Ore processing is a 24-hour operation. The procedure of ore processing can be seen ~~at~~ in figure 8. Ore is stockpiled<sup>(1)</sup> at the processing plant, and the process begins by feeding the ore into a hopper with a loader. The ore is conveyed and following crushing through a jaw crusher<sup>(2)</sup> to cone crusher<sup>(3)</sup>, the ore is fed into the semi autogenous grinding ballmill<sup>(4)</sup> along with water and lime is added to raise the pH of the ore. The grinding process reduces the rock to a slurry.

The ballmill is a large revolving cylinder. Rock is ground by the turning action of the mill, and impact from the hardened steel balls and the rock itself.

The slurry that is fine enough passes through the classifier<sup>(5)</sup> and then to a primary hydrocyclone<sup>(6)</sup>. This hydrocyclone classifies the ground rock particles according to size using centrifugal and gravitational forces to split the fine particles from the coarse particles.



The hydrocyclone<sup>(6)</sup> further classifies the slurry, with the coarse particles being directed to the ball mill<sup>(4)</sup> and fine particles reporting to the leaching tank<sup>(7)</sup> to leach the gold particles from the slurry. The slurry that remains after this process has a very fine particle size. Typically, 80% of the ore particles are less than 200 microns in size. Such a fine particle size is required for gold liberation. After leaching the gold from the leaching tank, the mixtures of gold and slurry ~~reporting were sent~~ directly to the absorption tank. The activated carbon was added to the absorption tank to attract the gold particles.

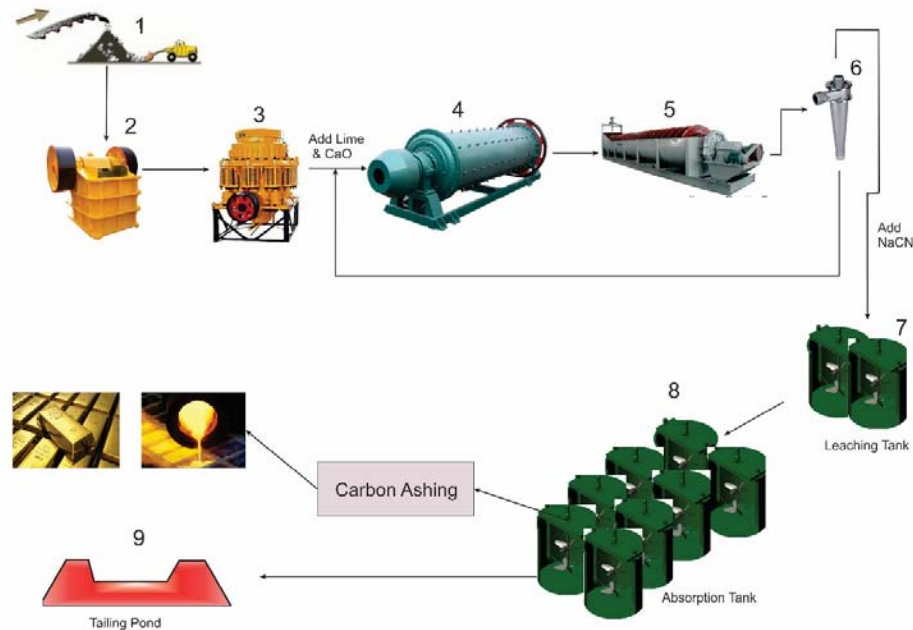


Figure (8). The procedure of ore processing system.

### ***Leaching and absorption***

The slurry of ground ore and lime moves into a series of eight to twelve leach tanks<sup>(7)</sup> where a sodium cyanide solution is added. The tanks provide sufficient retention time to allow the gold to be dissolved by the cyanide solution. Oxygen is added to assist in this process by airman machine. The slurry then moves through a series of carbon adsorption tanks<sup>(8)</sup>. While the leaching process continues in these tanks, the primary objective is to remove the gold from the solution. To achieve this, carbon is fed through the tanks and the gold adsorbs (attaches) to the carbon granules. By the time the slurry reaches the final adsorption tank, most of the precious metals have been removed. The barren slurry, now known as tailings, is pumped to the tailings storage facility<sup>(9)</sup>. Carbon is heated to 200 degrees C and get the crude gold and carbon have to be ashes. Crude gold need to be refined to get pure gold.

### ***Tailings***

Tailings are a slurry of around 30% solids and are deposited from the crest of the waste rock embankment via a series of spigots. Fresh tailings are deposited above water onto previously placed tailings. The material is predominantly silt size, but also contains clay and sand-sized particles. Immediately adjacent to the point of deposition into the pond the tailings contain a higher proportion of sand, because the sand particles settle out more quickly, while

on the other side of the pond they contain a higher proportion of clay. Consequently, the physical characteristics of the tailings vary laterally across the pond, and this forms some tailings 'beach' adjacent to the crest.

The tailings have low permeability, and as they consolidate the permeability reduces to the extent that they are generally less permeable than the natural soils that underlie the embankment. The reducing permeability means that seepage from the tailings mass decreases significantly with time. Following consolidation, the permeability of the tailings reduces by more than a factor of 10 compared with its permeability after initial deposition, to become generally less than 10<sup>-9</sup> meters per second. The permeability of the consolidated tailings is very low and is equivalent to that required for the liner of a modern landfill.

### **Conclusions and Recommendation**

While there are, some obvious analytical errors affecting the results of the cyanidation test as stated above, the results confirm that the ore can be easily and rapidly leached and recovered even at low cyanide strength and without lead nitrate addition. Hence it is recommended to lower the cyanide strength being maintained at the mills to 0.03% NaCN. It is also recommended to initially reduce the lead nitrate being added to not more than 25 g/mt of ore. Gradual phasing out of lead nitrate must also be considered especially while the mills are operating at very low pulp density of less than 25% solids. A shorter residence time for leaching (16-24 hours) and adsorption (>12-16 hours) should also be considered. Finally, the gold assaying capability of the laboratory should be strengthened in order to produce more accurate and consistent assay results.

### **Acknowledgement**

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