GOLD CYANIDATION AND CHARACTERIZATION OF ITAGUNMODI GOLD DEPOSIT USING CYANIDE FROM CASSAVA

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[1,2*]O.D. OGUNDARE, [1]A.R. ADETUNJI AND [1]M. O. ADEOYE
[1]Department of Materials Science and Engineering, Obafemi Awolowo University Ile Ife Nigeria.
[2]Engineering Materials Development Institute Akure Nigeria.
[suppiedee@yahoo.com, aderade2004@yahoo.com, madeoye@oauife.edu.ng]

ABSTRACT
This work has investigated gold cyanidation and characterization of Itagunmodi gold deposit using cyanide from cassava. The gold ore was subjected to selective removal of associated minerals, treated to varied concentrations of cyanide extracted from cassava and precipitation of the gold. The precipitated gold was characterized using optical microscope, SEM - EDX, EDXRF and XRFS. The result showed that after 24 hours of cyanidation using analar grade sodium cyanide of 60 mg/l, 10 g Itagunmodi gold ore concentrate yielded 0.096 g (96 mg) gold. Also, under the same condition, using cassava based cyanide concentration of 60 mg/l, 10 g Itagunmodi gold ore concentrate yielded 0.08 g (80 mg) gold. This work has shown that sourcing cyanide from cassava waste for gold leaching is the appropriate alternative to the conventional cyanidation.

Keywords: *gold cyanidation, Itagunmodi, cassava based cyanide*

INTRODUCTION

The oxidation of gold is a prerequisite for its dissolution in alkaline cyanide solution. Although gold is inert to oxidation, it is widely accepted that, in the presence of a suitable complex agent such as cyanide, gold is oxidized and dissolved to form the stable complex ion [Au $(CN_2)^-$]. Oxygen is reduced and hydrogen peroxide is formed as an intermediate product in the first step and becomes the oxidizing agent in the second step, leading to the following chemical reactions which proceed in parallel (De Andrade Lima and Hodouin, 2005; Senanayake, 2005) equation 1 and 2. Cyanidation techniques used in the gold industry today include heap or valley fill leaching followed by carbon adsorption (carbon-in-column adsorption), agitation leaching followed by carbon-in-pulp (CIP), or agitated carbon-in-leach (CIL). *In situ* leaching of gold is being researched by the Bureau of Mines, but is not used commercially at this time. Cyanidation is best suited to fine-grain gold in disseminated deposits. Heap or valley fill leaching is generally used to beneficiate ores containing less than 0.04 oz/t. CIP and CIL techniques, commonly referred to as tank or vat methods, are generally used to beneficiate ores containing more than 0.04 oz/t. These gold beneficiation cut-off values are dependent on many factors, including the price of gold and an operation's ability to recover the precious metal (van Zyl et al. 1988).

MATERIALS AND METHODS

All chemical reagents used in this work were of analytical grade and all stock solutions were prepared using distilled water.

Experimental Approach

The samples were collected from 2 pits from Itagunmodi in Atakumosa West LGA of Osun State. The pits were dug to 7 feet deep and 6 feet in width. Shovel, head pan as well as sample bags were used in collecting the samples. The samples were a mixture of stones (granite), pebbles, clay and water. 500 kg of samples from the two pits were collected and brought into the laboratory for beneficiation. Each gold ore as obtained from the mining site was soaked in water for three (3) days in plastic container. The slurry was stirred daily to allow the lumps to break down and highly dense gold grain to settle to the bottom. The particles of ore mineral were separated from those of the gangue by simply hand picking the gangue and other physical impurities.

The gold ore, obtained from Itagunmodi gold ore deposit, was weighed and other physical impurities were removed. The procedure for selective removal of associated minerals was carried out by successive addition of concentrated hydrogen tetraoxosulphate (VI) acid (H_2SO_4), concentrated hydrogen chloride (HCl) and sodium hydroxide (NaOH). The gold ore samples were exposed to varied concentrations from 7.5 mg/l to 60 mg/l of cyanide (CN^-) at intervals of 7.5 mg/l CN^- from cyanide solution obtained from cassava and sodium cyanide (NaCN) analar grade respectively. Acid washing was carried out on the aurocyanide solution in order to precipitate the gold by addition of concentrated H_2SO_4. Also, HCl was added to remove the co-precipitated iron. The precipitate was thereafter dried at 850°C. A second stage of acid washing was carried out by adding concentrated hydrogen trioxonitrate (V) acid (HNO_3) in order to remove any remaining gangue in the gold precipitate.

The chemical equation for the process is represented as follows (equation 1 – 4).

$$2Au_{(s)} + 4CN^{-}_{(aq)} + O_{2(g)} + 2H_2O_{(aq)} \longrightarrow 2Au(CN)^{-}_{2\,(aq)} + H_2O_{2(aq)} + 2OH^{-}_{(aq)} \quad (1)$$

$$2Au_{(s)} + 4CN^{-}_{(aq)} + H_2O_{2(aq)} \longrightarrow 2Au(CN)^{-}_{2\,(aq)} + 2OH^{-}_{(aq)} \quad (2)$$

The summation of the two partial reactions is presented in Eq. (3), as proposed by Elsner:

$$4Au_{(s)} + 8CN^{-}_{(aq)} + O_{2(g)} + 2H_2O_{(aq)} \longrightarrow 4Au(CN)^{-}_{2\,(aq)} + 4OH^{-}_{(aq)} \quad (3)$$

$$4NaAu(CN)_{2(aq)} + 4NaOH_{(aq)} \longrightarrow 4Au_{(s)} + 8NaCN_{(aq)} + 2H_2O_{(aq)} + O_{2(g)} \quad (4)$$

RESULT AND DISCUSSION

The results of gold cyanidation tests carried out to leach gold using various lixiviants and precipitants are depicted in Figure 1. It can be observed that as the concentration of the lixiviants increased, the gold yield obtained increased. It should be noted that further refining of the earlier gold yield obtained by acid leaching (H_2SO_4) has led to increased gold yield. This is because HNO_3 is a more powerful oxidizing agent than H_2SO_4. This result is part of the work published by Ogundare *et al.,* (2014).

The reaction mechanism governing the gold cyanidation process can be summarized as follows (equation 5 and 6).

After 24 hours of cyanidation using analar grade sodium cyanide of 60 mg/l, 10 g Itagunmodi gold ore concentrate yielded 0.096 g (96 mg). Also, under the same condition, using cassava based cyanide concentration of 60 mg/l, 10 g Itagunmodi gold ore concentrate yielded 0.08 g (80 mg). It is of interest to note that cyanidation is more effective in gold recovery than amalgamation process.

This work has been able to prove that sourcing cyanide from cassava waste for gold leaching is the appropriate approach. Although Mitchell *et al.* (1997) claims that both cyanidation and amalgamation processes have the same environmental impact, it may be that the authors have not taken into consideration the biodegradability of spent cyanide which makes it pose lesser environmental impact.

The percentage yield of gold from Itagunmodi gold ore, Ilesa- Nigeria and those from the other countries are as presented in Table1:

$$2Au_{(s)} + 4CN^{-}_{(aq)} + H_2O + {}^{1}/_{2}O_{2\,(g)} \longrightarrow 2[Au(CN)_2^{-}]_{(aq)} + 2OH^{-}_{(aq)} \quad (5)$$

$$2\,[Au(CN)_2^{-}]_{(aq)} + 2OH^{-}_{(aq)} + H_2SO_{4(aq)} \longrightarrow 2Au_{(s)} + SO^{-}_4 + 4HCN_{(l)} \quad (6)$$

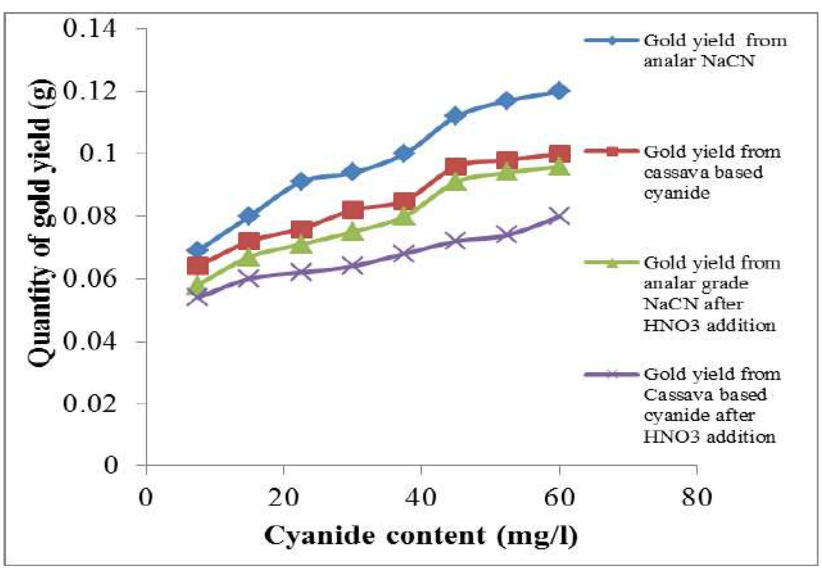


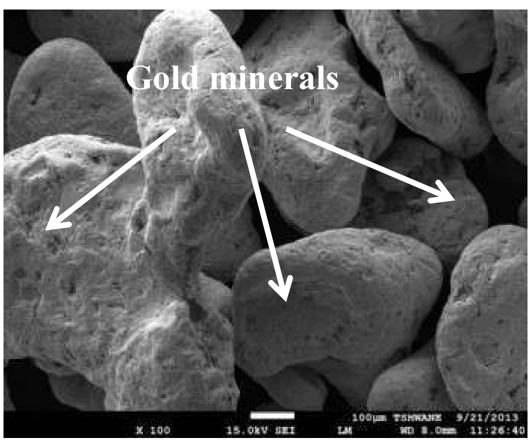
Figure 1: Effect of cyanide content on the quantity of gold yield through analar grade NaCN and cyanide solution from cassava.

These results have shown that the Itagunmodi (Nigeria) gold ore deposit is richer in native gold than those of Ijero Ekiti (Nigeria), Igun (Nigeria), Australia and Saudi Arabia deposits. According to Lewis and Martin (1983); and Robinson (1983), Australia and Saudi Arabia deposits contain mainly gold in the form of gold sulphide. The sulphide ore did not allow the direct attack of the gold particles by the cyanide solution in the ore because gold particles were locked in the sulphides. Extraction of gold from Igun deposit did not pass through acid leaching after cyanidation to unlock the residual gold particles. Baba *et al.* (2011) have reported a study on the dissolution kinetics and solvent extraction of total gold from Ijero-Ekiti (Nigeria) gold ore deposit by hydrochloric acid leaching followed by extraction with Tributylphosphate (TBP) in kerosene. In this work, double acid washing procedure has been employed. On the gold yield, with 60 mg/l cyanide content of analar grade sodium cyanide, 0.96 % gold was recovered while with 60 mg/l cyanide content of cassava based cyanide, 0.8 % was recovered. In terms of gold recovery efficiency, the performance of analar grade sodium cyanide is greater than cassava based cyanide by a difference of 0.16%.

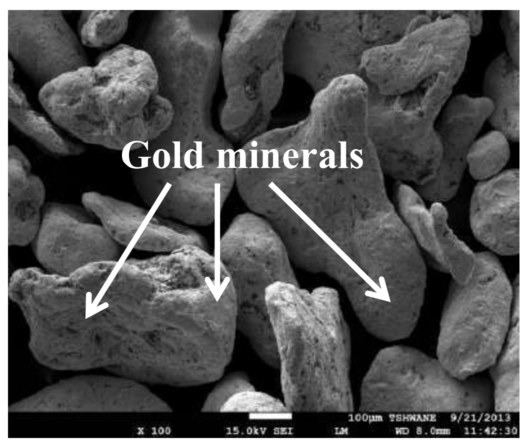
Comparing Plates 1 (a) and 2 (b), it can be observed that the gold leached through sodium cyanide analar grade and cyanide solution from cassava has a lot of similarities. It can be observed that the gold grains have curved edges with rough surfaces due to corrosive effects from the cyanidation procedures. Also, it can be observed that gold grains leached through sodium cyanide analar grade and cyanide solution from cassava as shown in Plates 1 (a) and 1 (b) have irregular shapes and without impurities. This attests to the fact that gold leached through sodium cyanide analar grade and cyanide solution from cassava have same quality.

Table 1: Comparison of the percentage yield of gold from Itagunmodi gold ore with other deposits

Country	Yield (mg/100 g of ore)	%Yield
Itagunmodi, Atakumosa LGA (Nigeria)	96/80	0.96/ 0.8
Ijero Ekiti (Nigeria) (Baba *et al.*, 2011)	85.28	0.85
Itagunmodi, Atakumosa LGA (Nigeria) (Adetunji, 1991)	27.2/16.48	0.27/0.16
Igun, Atakumosa LGA (Nigeria) (Mesubi *et al.*, 1991)	33.00	0.330
Papua, Australia (Robinson, 1983)	2.86	0.00286
Mahd Adh Dhahab Saudi Arabia (Lewis and Martin, 1983)	2.60	0.00260



(a)



(b)

Plate 1: SEM micrographs of the precipitated gold grains (a) through sodium cyanide, (b) through cyanide solution from cassava

The result of the attached EDX (Table 2) showed the composition of the ore and the presence of gold elements (6.4 wt. %). Other associated elements discovered are carbon, nitrogen, aluminium, copper, potassium, titanium and iron. These are in tandem with elements/ compounds found when XRFS was used for the same purpose as described in Table 3. However, the difference in the values obtained between the attached EDX and XRFS may be due to the variation in the distribution of the gold and its associated minerals at the point of sample testing. In order words, exactly the sample portion of the ore may not have been examined even when thoroughly mixed.

The chemical analysis (Table 3) showed that Itagunmodi gold ore and gold extract contain magnesium, aluminium, silicon, phosphorus, sulphur, potassium, calcium, titanium, vanadium, chromium, manganese, cobalt, iron, nickel, copper, zinc, arsenic, yittirium, lead, tungsten, gold, silver and rhobium. The presence of these associated minerals has been earlier reported by (Ariyibi *et al.,* (2011); Elueze, (1997); Mesubi *et al.,* (1999). One striking feature is that the high quantity of iron (Fe) discovered in the ore (23 %) may be as a result of the large composition of laterite sand in the ore during mining process. The high quantity of iron was observed to have been drastically reduced after cyanidation process to 0.56 % and 0.89 % respectively in gold leached using 60 mg/l analar sodium cyanide and gold precipitated using 60 mg/l cyanide solution from cassava. Also, titanium oxide which was found in high quantity (31%) in the ore has been reduced after the cyanidation process to 0.3 % and 0.5 % respectively. However, it is surprising to observe a sudden increase in the amount of tungsten oxide from 6 % in the ore to about 102 % and 91% respectively.

Table 2: Energy Dispersive X-Ray (EDX) Analysis attached to Scanning Electron Microscope of the gold ore and precipitated gold

a. Itagunmodi Gold Ore

Element	Weight%	Atomic%
C K	15.39	28.53
O K	37.06	51.59
Al K	6.95	5.73
Si K	4.20	3.33
Ti K	5.74	2.67
Fe K	5.38	2.15
Cu L	6.32	2.22
Zr L	12.56	3.07
Au M	6.40	0.72
Totals	100.00	

b. Leached gold by analar NaCN

Element	Weight%	Atomic%
C K	5.55	30.03
N K	2.96	13.65
O K	5.75	23.35
Al K	0.86	2.08
Ti K	0.85	1.15
Fe K	0.84	0.97
Cu L	1.93	1.98
Au M	81.00	26.71
Po M	0.26	0.08
Totals	100.00	

c. Leached gold by CN^- from cassava

Element	Weight%	Atomic%
C K	9.65	43.80
N K	3.50	13.62
O K	5.57	18.93
Al K	0.39	0.79
Fe K	0.70	0.69
Au M	80.19	22.19
Totals	100.00	

Table 3: Energy dispersive-x ray fluorescence spectrometry (EDXRFS) of the precipitated gold

	Gold ore	**Gold Extracted using 60 mg/l Sodium Cyanide Analar**	**Gold Extracted using 60 mg/l Cassava based cyanide**
Element	Content (ppm)	Content (ppm)	Content (ppm)
Mg	0.0478	0.4507	0.3081
Al	0.6538	0.7153	0.5887
Si	2.1584	0.6043	0.5367
P	0.4485	2.2342	2.0426
S	0.3998	7.0327	6.1424
K	0.0000	0.0000	0.0000
Ca	0.2197	0.0593	0.0757
Ti	30.9081	0.2533	0.5112
V	0.2328	0.0079	0.0114
Cr	0.0000	0.0021	0.0011
Mn	0.7312	0.0099	0.0201
Co	0.0039	0.0030	0.0000
Fe	23.1568	0.5682	0.8987
Ni	0.0609	0.0412	0.0450
Cu	0.0661	0.0646	0.0875
Zn	0.1021	0.2687	0.2682
As	0.0000	0.0000	0.0000
Pb	0.0156	0.0000	0.0000
W	6.1191	102.4461	90.5610
Au	19.0095	208.6410	191.9714
Ag	0.0362	0.0186	0.0240
Rb	0.0091	0.2900	0.2619

CONCLUSION

1. After 24 hours of cyanidation and cyanide content of 60 mg/l on 10 g gold ore concentrate, the analar grade sodium cyanide yielded 0.096 g gold while the cassava based cyanide yielded 0.08 g gold.
2. The SEM revealed similar curved edges, irregular shapes, purity and quality for the precipitated gold from cyanide solution from cassava and sodium cyanide analar grade.

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