TECHNICAL NOTE

COMPARATIVE CYANIDE AND THIOUREA EXTRACTION OF GOLD BASED ON CHARACTERIZATION STUDIES

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Abstract This study involved preliminary laboratory test work to identify the relative leaching response to cyanidation and thiourea leaching of an oxidized low grade gold ore based on characterization studies. Huge reserves of gold deposits have been reported from different parts of Iran, especially at Neishaboor area with gold grade of approx 4 ppm. For the mineralogical composition, the nature of the minerals, type of gold, chemical characters and the suitable mesh of grind which play vital role in finding out suitable flowsheet design, the representative samples were subjected to detailed characterization studies and found that, the ore is oxidized and gold is present partly in the from of solution in quartz veins as well as in the form of free particles in iron hydroxide specially hematite which is the product of pyrite oxidation. Quartz, hematite, calcite and feldspar are the main minerals present in the order of abundances. Sieve analysis and distribution of gold particles in different sieve fractions shows most of the gold are distributed bellow 2000 microns. Therefore based on characterization studies, the potential of an alternative lixiviant like thiourea leach have been determined and found that under optimized conditions cyanide leaching of the ore performs (extraction of 95% after 240 hours) better than thiourea leaching (extraction of 10% after 240 hours and 67% after 662 hours).

Key Words Thiourea, Cyanidation, Mineralogy, Gold Ores, Leaching, Extraction

چکیده در این مقاله نتایج مطالعات مقدماتی و خواص سنجی نمونه و از طرفی بررسی مقایسه ای روش استحصال طلا با دو محلول سیانور و تیواوره بر نمونه ای از کانه طلای نیشابور آورده شده است. برای دستیابی طرح بهینه، نمونه های جمع آوری شده تحت مطالعات دقیق قرار گرفته و مشخص شد که ماده معدنی مورد نظر به شدت اکسیدی بوده و طلا به صورت محلول در کوارتز و نیز به شکل ذرات آزاد در هیدروکسیدهای آهن، بخصوص هماتیت که محصول اکسیداسیون پیریت است، قرار دارد. نتایج مطالعات مقدماتی نشان داده که کوارتز، هماتیت، کلسیت و فلدسپار مهمترین کانیهای موجود در ماده معدنی است. با استفاده از مطالعات میکروسکوپی و آزمایشهای مقدماتی، درجه آزادی کامل ذرات طلا زیر ۷۴ میکرون تشخیص داده شد. با استفاده از نتایج مطالعات مقدماتی، روش مقایسه ای لیچینگ با دو محلول سیانور و تیواوره برای زیر ۲ میلیمتر صورت گرفت و مشخص شد که بازیابی طلا به روش لیچینگ سیانور و در شرایط بهینه (بازیابی ۹۵ درصد در مدت ۲۴۰ ساعت) بهتر از لیچینگ توده ای به روش تیواوره (بازیابی ۱۰ درصد در مدت ۲۴۰ ساعت و ۶۷ درصد در مدت ۶۶۲ ساعت) می باشد.

1. INTRODUCTION

Gold is usually associated with complex sulfide ores and conventional straight cyanidation is used to extract gold if they occur in the boundary of the mineral particle [1]. Therefore the characterization studies of an ore deposit and its mineral assemblages determine the mining methods, extraction and, in

TABLE 1. Basic Properties of Lixiviants used for Gold Extraction [6].

Sl No	Reagent	Type of oxidant	Type of Au complex in solution	Optimum PH
	Alkaline system			
1	Cyanide	O_2	$Au(CN)^{-1}$	>10
2	Ammonia cyanide	O_2	$Au(CN)^{-2}$	>10
3	Organic Nitriles	O_2	$Au[CH(CN)_2]_2^{-1}$	>7
4	Calcium cyanoform	O_2	$Au[C(CH_3)_3]_2$	>10
	Neutral system			
1	Thiosulfate	O_2	$Au(S_2O_3)_2^{-3}$	>7
2	Bromocyanide	Br,CN	$Au(CN)_2$	7
3	Bromine	Br_2	$AuBr_4$	7
	Acid system			
1	Chlorine	Cl_2	$AuCl_4^-$	<2
2	Ferric chloride	Fe^{+3}	$AuCl_4^-$	<2
3	Thiocyanate	Fe^{+3},H_2O_2	$Au(SCN)_4^-$	<3
4	Thiourea	Fe^{+3},H_2O_2	$Au(CS(NH_2)_2)_2^+$	2-3

TABLE 2. Chemical Analysis of Gold Sample.

Constituents	Weight %
SiO_2	**84.5**
Al_2O_3	**5.2**
Fe_2O_3	**5.0**
CaO	**0.98**
MgO	**0.16**
Na_2O	**0.09**
K_2O	**0.17**
Au	**4 ppm**
Others	**3.36**
Total	**100**

particular, the performance of all beneficiation and chemical process involved in precious metals extraction. Consequently, a good understanding of the mineralogy of the matrix material (sample) is required to design or operate an extraction or optimum efficiency [2, 3,4,5].

Cyanidation has been the standard process for gold recovery since cyanide was firstly applied as an optimum lixiviant for gold, nearly a century ago [1]. Although this method has been used commercially for the past years, there are refractory ores that are not amenable to cyanidation method. Many alternate lixiviants have been studied for extraction of gold, especially those of halogens, thiourea, thiosulfate and malononitrile, however only thiourea has found some industrial application. Table 1.shows some basic properties of lixiviants used for gold extraction [6].

Thiourea leaching of Au and Ag was first reported by Reynolds [7] and has attracted the interest of many investigators [8,9]. Any consideration of thiourea usage must be taking into account the relative costs vis-à-vis cyanide. Thiourea consumption is at least twice that of cyanide in the best of circumstances, and costs at least four times as much. However, its main attraction could be its relative non – toxicity, its selectivity for the precious metals, specially Au, its superior kinetics and specific applicability in certain circumstances [8].

2. EXPERIMENTAL METHODES

Characterization A part of bulk sample received, was subjected to size reduction very carefully in a jaw and followed by roll crushers in closed circuit with a single deck screen to give a crushed product

TABLE 3. Sink and Float Tests on Different Size Fractions.

Separation densities (gr/cm^3)	Wt	Gold	Distribution	Cum. Distribution
-2.6	2.5	0.5×10^{-4}	0.34	0.34
2.6-2.7	25	0.5×10^{-4}	3.48	3.82
2.7-2.8	39.5	0.8×10^{-4}	8.80	12.62
2.8-2.9	7.5	3×10^{-4}	6.27	18.89
2.9-3	10	8×10^{-4}	22.29	41.18
3-3.1	7.5	10×10^{-4}	20.90	62.08
+3.1	8	17×10^{-4}	37.92	100
total	100	3.588×10^{-4}	100	

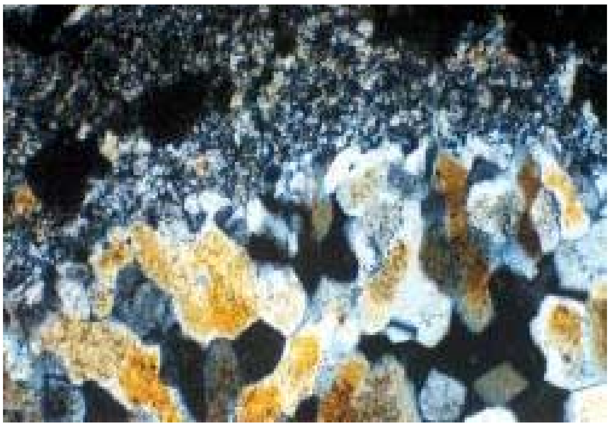

Figure 1. Microphotograph of large particles of quartz with small crystals of quartz and feldspar(X 20$\times$12.5 ppl).

Figure 3. Microphotograph which seems to be of gold particle (110$\times$70 μ) in iron oxides (brown coloure), (X 20$\times$12.5 ppl).

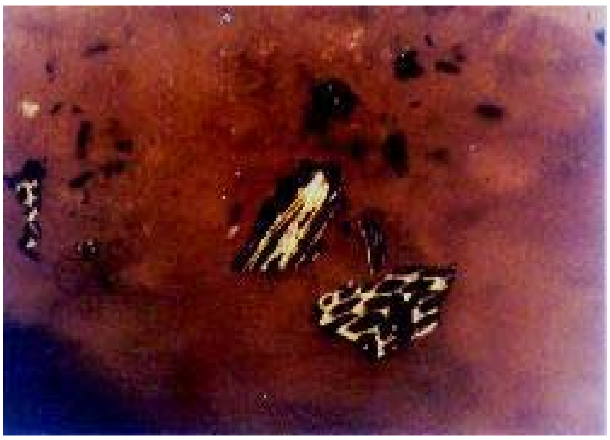

Figure 2. Microphotograph of Boxwork structure of pyrite subjected to oxidation process (X 20$\times$12.5 ppl).

of -6 mesh (ASTM) fraction. The sampling techniques like Jones riffles and coning and quartering methods adopted and representative samples prepared for further studies. Table 2 shows the results of chemical analysis. The mineralogical analysis and modal percentage of grain size of the constituent minerals is also shown graphically in Figures 1, 2 and 3. The results show that, the ore is may be oxidized and gold is present partly in the form of solution in quartz veins as well as in the form of some free particles in iron hydroxides specially, hematite which is the product of pyrite oxidation. Figure 4 shows the results of size fraction analysis and distribution of gold particles in different sieve fractions. The results of sink and float tests is also

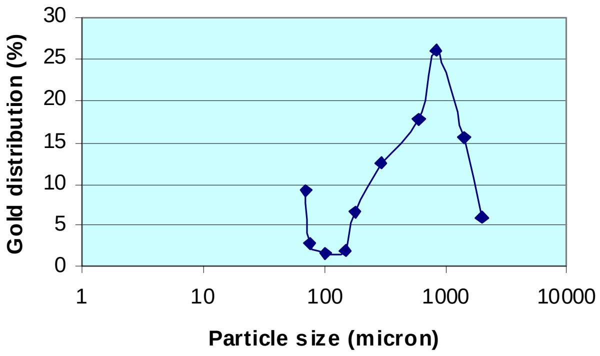

Figure 4. Distribution of gold particles in different sieve fractions.

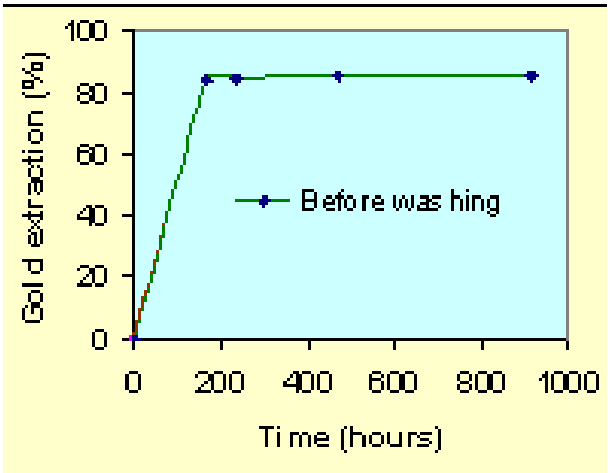

Figure 5. Conditions of optimized results obtained using cyanide reagent.

shown in Table 3.The microscopic studies shows that though some of the particles are bellow 74 microns but most of the gold particles are distributed in the sizes 500 to 2000 microns (Figure 4 and Table 3).

Leaching Experiments Sodium cyanide, lime, H_2O_2, thiourea, ferric sulphate and sulfuric acid were all chemicals of reagent grade and the liquid media was distilled water. Before starting the leaching tests, a standard twenty four hour cyanidation and thiourea leaching were carried out in a reactor stirred at 200 rpm. Leaching was carried out with 1 kg of ore grined to -74 microns (liberation size), using oxidizing agent 1.5kg/t 1 kg/t NaCN with and run for 24 hours at pH 11 percent solid by weight was 35. The thiourea leaching was carried out

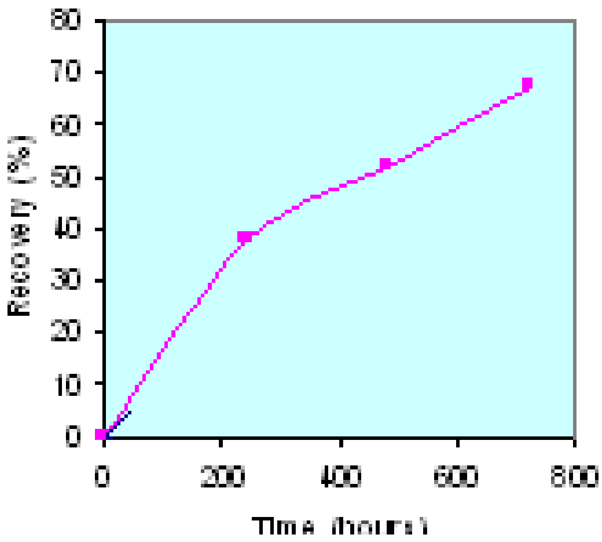

Figure 6. Conditions of optimized results using thiourea.

with 20kg/t reagent and ferric sulphate (10 kg/t) and sulphuric acid to ensure an operating pH range of 1.5-2 for 24 hours. All pregnant solutions were assayed by conventional atomic absorption spectrophotometry while the residues were fire – assayed. The results indicate that thiourea leaching performs (96.5% extraction at 16 hours) better than (96% extraction at 24 hours) cyanidation.

Leaching The gold leaching cells were made of glass and plastic, with a 10 litre capacity at room temperature. The tests were made with ore crushed carefully to -2000 microns at the pH of desired level. Then the cyanide and thiourea were added along with oxidizing agents. Number of parameters like concentration of reagent, pH, and oxidizing agent and particle size varied separately. A 25ml-leached liquid were removed with a pipette at every one hours for a period of one week to investigate the constant level of pH and consumption of reagents. The same amount were pipette every three days for a month and at the end of the tests. The residues after a month were repulped and washed carefully for number of times. All pregnant solutions were assayed by conventional atomic absorption spectrophotometry while the residues were fire-assayed. The optimized results were obtained are shown in Table 4 and 5 and illustrated graphically

TABLE 4. Optimized Results Obtained Using Cyanide Reagent.

Recovery after washing (%)	Recovery (%)	$KMnO_4$ (kg/t)	pH	Size of the particle (mm)	NaCN (kg/t)	Leaching time (hours)
-	83. 7	1. 5	11	-2	0. 8	168
-	84. 6	1. 5	11	-2	0. 8	236
-	-	1. 5	11	-2	0. 8	472
95. 2	84. 8	1. 5	11	-2	0. 8	914

TABLE 5. Optimized Results Obtained With Thiourea.

Recovery After washing (%)	Recovery (%)	Ferric sulphate (kg/t)	pH	Thiourea (kg/t)	Leaching Time (hours)
-	-	10	2	20	
-	25. 6	10	2	20	240
-	40. 4	10	2	20	480
67.6	55. 2	10	2	20	720

in Figures 5 and 6.

3. RESULTS AND DISCUSSION

Table 2 presents high percentage of SiO_2 and petrographic investigation (Figure 1) confirms that quartz is the main gangue mineral, in which the gold particles present partially in the form of solution. However some gold particles may also present as inclusions in hematite (Figure 3), which is the product of pyrite oxidation (Figure 2). This investigation shows that the ore is not refractory in nature but it may be in the free state and the situation of tectonic criteria, converted the zones in to crushed product, thus made the ore amenable to heap leaching. Figure 4 and Table 5 clearly shows that. Most of the gold particles are distributed in the size ranges of 500 to 2000 microns and it is somehow supplemented with the petrographic studies. Figure 5 and 6 shows that thiourea gave a low yield in comparison to cyanidation. The tests showed that the best conditions resulted in a gold extraction rate of 67% after a month and thiourea consumption of 20 kg/t. The main reason for this poor performance was related to size of the particle (-2000 μ), which is not suitable for such leaching rather than agitation leaching using finer sizes (-74 μ), which performs better results. The experimental approach used in this part of project differs from that of a previous publication [8].

An examination of Figure 5 indicates that, in an experimental approach at low cyanide content, the leaching kinetics are really better than in thiourea leaching. The experimental approach used in this part is in agreement with other investigators [2, 8]. In fact, an average of a month of processing was required to reach the gold extraction to the tune of half of the amount that obtained by cyanidation.

4. CONCLUSIONS

The authors have drawn the following conclusions:

The gold deposits of Neishaboor area of Iran was subjected to characterization and leaching experiments and found that:

1. The ore is may be oxidized and gold is present partly in quartz as well as in the form of free particles in hematite which is the product of pyrite oxidation.
2. Most of the gold particles are distributed in sizes between 500 to 2000 microns.
3. Standard tests on samples grind to -74 microns clearly show that thiourea leaching performs better than cyanidation.
4. Leaching on samples crushed to -2000 microns clearly shows that cyanidation performs better than thiourea leaching.

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