

EXTRACTION OF GOLD AND SILVER BY AGITATION CYANIDATION PROCESS FROM COMPLEX ORE OF SHOUGHUR AREA CHITRAL, KYBER PAKHTUNKHWA PAKISTAN

Sajjad Hussain^{1*}, Nisar Mohammad¹, Zahid Ur Rehman¹, Noor Mohammad¹, Ishaq Ahmad¹,
Naseer Muhammad Khan² and Salim Raza¹

ABSTRACT

The gold cyanidation/leaching process is the most versatile processing technique used for extraction of gold utilizing different cyanidation parameters likes grinding time, pH, cyanidation time, sodium cyanide (NaCN) and lime CaO.. The efficiency of cyanidation process depends on dosage of each parameter. In present research work the extraction of gold and silver by cyanidation process from shoughur area of district Chitral, Khyber Pakhtunkhwa was carried out at laboratory scale. The three representative samples ground at time 25, 30 to 35 minutes and roasted at 650 oc for 1 hour were subjected to agitation cyanidation process at varying dosage of pH from 10 to 11.13 , CaO from 0.5 to 1.5 gm/kg, NaCN varies from 1 gram to 5.93 gram and cyanidation time varies from 0 to 39 hours. The maximum grade of 71.82 ppm with 99.03% extraction/recovery of gold and 34.34 ppm with 73.83% extraction of silver was obtained for 30 minutes ground sample at dosage of sodium cyanide (NaCN) of 5.33 gram, pH 10.40, CaO of 1.5 gram, and cyanidation time of 37 hours as compared to 25 and 35 minutes ground samples. The cyanidation process was also applied on un-roasted ground ore samples at 30 and 35 minutes, pH 10.40, lime of 1.5gm/kg and varying cyanidation time from 2 to 37 hours. The maximum grade of gold 11.95 ppm and silver 11.50 ppm was extracted. Based on the comparative analysis of result it is concluded that cyanidation process on roasted ore samples gives better results as compared to un-roasted ore samples.

KEYWORDS: *Complex ore, Cyanidation process, Assay, Recovery*

INTRODUCTION

The complex ore containing gold, silver, lead and antimony occurred at Shoghore area of district Chitral, Khyber Pakhtunkhwa Pakistan. The reserve of complex ore estimated by Mineral Department Khyber Pakhtunkhwa about 50,000 tons. Geologically the zone may be designated as sulphide mineralization zone and an altered carbonate body was also detected spreading over a linear distance of about 5 Km, with average thickness of 30 feet starting from Shoghore bridge (Chitral Garam Chashma road) towards South-East. The deposit contains up to 50 g/t of gold and silver up to 700 g/t (DGMM, 2005).

Gold and other base metals extractions from complex ore is emerging issue in Pakistan. Different researcher's worldwide have developed different processing techniques for gold and other base metal extraction. Among these processing techniques gold cyanidation got more attentions and is considered more efficient in extraction of gold and others metals from complex ore because the cyanide

solution dissolve the precious metals form complex ores and makes it easy to separate the interested metal. This process has been successfully applied in the extraction of gold and silver from complex ore for the past 100 years. It is revealed from literature that cyanide and oxygen work as ligand and oxidant respectively and both play vital roles in the gold and silver extractions (Akcil, 2002; Xianwen at al., 2012; Xie, 2009; Kondos at al., 2009). Gold cyanidation is an electrochemical process, in which gold is first oxidized and then changed to the stable ion $[Au(CN)_2]^-$, oxygen is reduced, and hydrogen peroxide decomposed (Andrade & Hodouin, 2006; Senanayake, 2008; Ubaldin at al., 1997; Habashi, 1992; Marsden, 1992). The presence of sulfides ore effect gold dissolution into different ways. In this regards different researchers presents two hypotheses. One theory suggests that soluble sulfide (S_2^- or HS^-) made from mineral dissolution when reacts with gold produces a passive film which decreases the effectiveness and extent of leaching and the other theory suggests that soluble sulfide (S_2^- or HS^-) made from mineral dissolution when reacts with gold a dynamic coupling of reduction generates at the surface

1 Department of mining engineering, University of engineering and technology, Peshawar, Pakistan*

2 Department of mining engineering, BUITEMS Quetta, Pakistan

of sulfide mineral, which starts oxidation on the gold grains and as a result the consumption of cyanide and oxygen increases (Xianwen at al., 2012; Habashi, 1992; Marsden, 1992; Karimi at al., 2010; Kondos at al., 1995; Weichselbaum at al.,1989). The pretreatment of complex ore for cyanidation process includes the basic mineral processing steps like drying, comminution, particle size analysis and roasting. Generally the roasting of samples at temperature of 650 °c is carried out for increasing the amenability of sample to cyanidation (Roshan, 1990; Dunn, 1997; Celep at al., 2009)..

The present research was focused on agitation cyanidation process for extraction of gold and silver from complex ore collected from shoughur area. The agitation cyanidation process was applied on roasted and un-roasted samples at varying dosage of pH from 10 to 11.13 , Ca (OH)₂ from 0.5 to 1.5 gm/kg, NaCN varies from 0.31gm to 1gm and cyanidation time varies from 0 to 39 hours. Based on results obtained from roasted and un-roasted agitation cyanidation process it was concluded that cyanidation of roasted samples give better results as compared to cyanidation of un-roasted samples.

MATERIALS AND METHODS

Samples preparation

12 kg sample was collected from the bulk sample of Shoghore area, District Chitral, Khyber Pakhtunkhwa Pakistan. The sample was crushed in jaw crusher and roll crusher to reduce the size of the sample to -2mm. The crushed sample was divided into three (3) samples of weighing 4 kg and dried in an oven at 110 C° for two hours to remove the moisture and was feed into rod mill for further size reduction at different grinding time of 25, 30, and 35 minutes. The sieve analysis of ground sample was carried out for different ground samples to check the liberation of gold and silver particles under microscope. The ground sample of 25, 30 and 35 minutes was split into six (6) samples through sample splitter machine in order to get homogenous sample of weighing approximately 2 kg each. 1 kg sample from each ground sample at time 25, 30 and 35 minutes was roasted due to refractive nature of gold in a muffle furnace at a temperature of 650 C° for 1 hour.

Cyanidation process

The agitation cyanidation process was used for extraction of gold and silver. For agitation cyanidation process the slurry samples were prepared from three ground samples (25, 30 and 35 minutes) by adding 1000gram of water in each sample. The pH of the each slurry sample was adjusted by adding CaO. Different dosage of sodium cyanide at different time duration was added in each slurry sample and agitated at constant speed of 45 RPM for complete mixing. The 5 ml Samples were collected periodically for each slurry sample for gold and silver extraction analysis at varying dosage of pH from 10 to 11.13 , CaO from 0.5 to 1.5 gm/kg, NaCN varies from 1 gram to 5.93 gram in time duration of 0, 4, 18, 24, 28, 35, 37, and 39 hours and the analysis of gold and silver was carried out by atomic absorption spectrometer. The cyanidation process was also applied on un-roasted ground ore samples at 30 and 35 minutes, pH 10.40, lime of 1.5gm/kg, NaCN of 5.33gm and varying cyanidation time from 2 to 37 hours.

RESULTS AND DISCUSSIONS

Mineralogical and Chemical analysis of head sample

Thin sections analysis of head samples were carried out using polarizing microscope. The microscopic study result shows the presence of iron pyrites, carbonate, quartz and gold grains were found interlocked in ore. Therefore roasting of ore was recommended to release the gold grains prior to cyanidation leaching process. The gold present in the ore was observed to have straight boundaries.

The chemical composition of head sample was determined in the laboratory by atomic absorption spectrometer. The results are presented in table 1.

Particle size distribution (PSD)

The sieve analysis of 25, 30 and 35 minutes ground samples were carried out in laboratory using sieve shaker. The purpose of grinding time is to reduce the size and as well as liberate the valuable particles from gangue particles. The PSD curves for ground samples at 25, 30 and 35 minutes is shown in figure 1.

Table 1. Chemical composition of head sample

Au (ppm)	Ag (ppm)	Pb %	Sb %	SiO ₂ %	Cu %	SO ₄ %	Mn %	Fe %
15	45	31.82	14.45	9.92	0.40	20.31	3.28	0.21

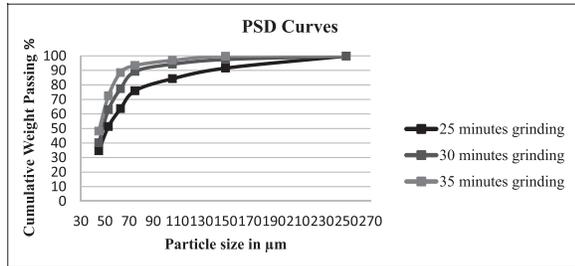


Figure 1: PSD curves for 25, 30 and 35 minutes ground sample

Figure 1 shows that production of fine particles are increases as grinding time increases from 25 to 35 minutes. The ground samples were studied under microscope for liberation of gold and silver grains. It was concluded based on microscopic analysis that maximum grains of gold was liberated in ground sample at 30

minutes. The microscopic analysis of ground sample at 35 minutes revealed that the maximum slimes particles were produced. Due to production of slimes it decreases the cyanidation efficiency as the results are shown in table 4.

Agitation cyanidation process results

Three ground samples at 25, 30 and 35 minutes were subjected to agitation cyanidation process at at varying dosage of pH from 10 to 11.13 , CaO from 0.5 to 1.5 gm/kg, NaCN varies from 1 gram to 5.93 gram and cyanidation time varies from 0 to 39 hours. The product obtained for each sample was analyzed by atomic absorption spectrometer (AAS) for gold and silver analysis. The results are presented in table 2, 3 and 4 for ground sample at 25, 30 and 35 minutes respectively.

Table 2. Cyanidation test results for 25 minutes ground sample

Time Hrs	Contents and additions					Solutions			AAS Result	
	Solid (g)	Water (ml)	NaCN (g)	Cumulative dosage of NaCN (g)	CaO (g)	NaCN %	pH Pre.	pH Post	Au ppm	Ag Ppm
0	1000	1000	1	1	1.5	0.1	7.01	10.51	-	-
4			0.82	1.82		0.182	10.49	10.49	5.31	18.58
18			0.79	2.61		0.261	10.45	10.45	15.66	39.83
24			0.72	3.33		0.333	10.41	10.41	16.13	44.56
28			0.47	3.8		0.38	10.37	10.37	35.43	53.9
35			0.82	4.62		0.462	10.35	10.31	43.21	60.85
37			0.55	5.17		0.517	10.30	10.31	44.44	68.7
39			0.55	5.72		0.572	10.30	10.31	34	57.54

Table 2 revealed that the maximum grade extracted for gold is 44.44 (ppm) and silver 68.70 (ppm) at dosage of sodium cyanide (NaCN) of 5.17 gram, pH of 10.31, CaO of 1.5 gram, and cyanidation time of 37 hours.

Table 3 revealed that maximum grade extracted for gold is 71.82 ppm and silver 39.93 ppm at dosage of sodium cyanide (NaCN) of 5.33 gram, pH 10.40, CaO of 1.5 g, and cyanidation time of 37 hours.

Table 4 revealed that maximum grade extracted for

gold is 47.27 (g/t) and silver is 67.86 (g/t) at dosage of sodium cyanide (NaCN) of 3.49 gram, pH of 10.40, CaO of 1gram, and cyanidation time 37 of hours.

Comparative analysis of cyanidation results for 25, 30 and 35 minutes ground sample

The maximum assay of 71.82 ppm for gold and 39.93 ppm for silver was obtained for 30 minutes ground sample as compared to ground sample at 25 and 25 minutes. The maximum percent of extraction of about

Table 3. Cyanidation test results for 30 minutes ground sample

Time	Contents and additions					Solutions			AAS Results	
Hrs	Solid (g)	Water (ml)	NaCN (g)	Cumulative dosage of NaCN (g)	CaO (g)	NaCN %	pH Pre.	pH Post	Au ppm	Ag Ppm
0	1000	1000	1	1	1	0.1	7.02	11.05	-	-
4			0.82	1.82		0.182	10.73	10.73	1.93	8.63
18			0.79	2.61		0.261	10.69	10.69	12.73	20.87
24			0.73	3.34		0.334	10.51	10.51	12.75	20.88
28			0.57	3.91		0.391	10.50	10.50	34.40	28.84
35			0.82	4.73		0.473	10.48	10.48	54.42	34.34
37			0.60	5.33	0.533	10.40	10.40	71.82	39.93	
39			0.60	5.93	0.593	10.38	10.40	56.73	0.40	

Table 4. Cyanidation test results for 35 minutes ground sample

Time	Contents and additions					Solutions			AAS Results	
Hrs	Solid (g)	Water (ml)	NaCN (g)	Cumulative dosage of NaCN (g)	CaO (g)	NaCN %	pH Pre.	pH Post	Au ppm	Ag Ppm
0	1000	1000	1	1	1	0.1	6.99	11.13	-	-
4			0.152	1.152		0.1152	10.90	10.90	2.00	12.50
18			0.75	1.902		0.1902	10.70	10.63	10.06	26.04
24			0.385	2.287		0.2287	10.50	10.45	11.02	26.46
28			0.491	2.778		0.2778	10.38	10.38	10.37	25.34
35			0.310	3.088		0.3088	10.37	10.51	28.88	29.80
37			0.405	3.493		0.3493	10.35	10.35	47.27	67.86
39			0.405	3.898		0.3898	10.32	10.35	47.04	39.74

Table 5. Percent extraction/Recovery

Cyanidation time in hrs	Calculated Extraction/Recovery for 25 minutes ground sample		Calculated Extraction/Recovery for 30 minutes ground sample		Calculated Extraction/Recovery for 35 minutes ground sample	
	Au %	Ag %	Au %	Ag %	Au %	Ag %
0	-	-	-	-	-	-
4	10.42	27.93	2.83	25.89	4.37	0.30
18	30.38	59.26	17.77	62.04	21.76	39.81
24	30.97	66.42	18.34	61.40	23.61	40.06
28	67.33	78.57	49	83.92	21.98	37.97
35	75.60	87.53	76.66	98.09	60.57	44.17
37	82.59	94.23	99.03	73.83	97.99	99.53
39	62.46	81	78.07	1.15	96.38	57.55

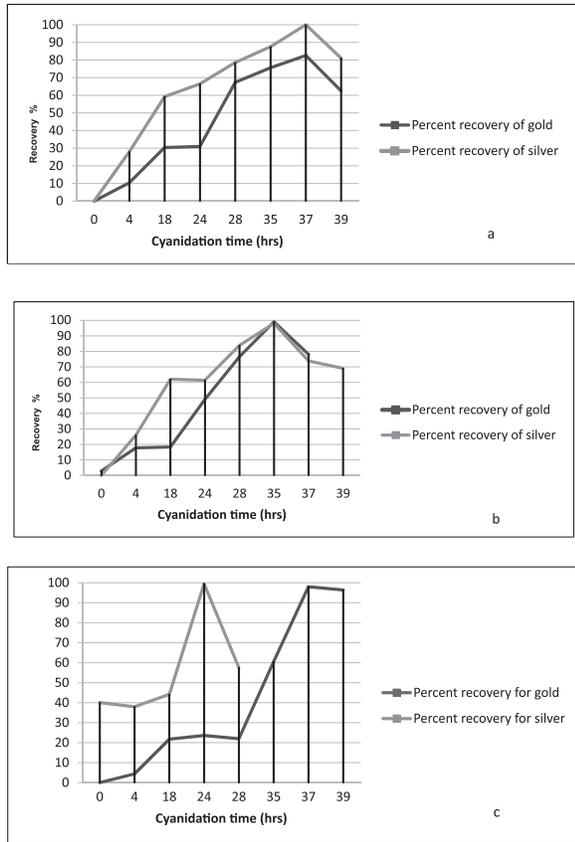


Figure 2: Percent recovery of gold and silver for 25(a), 30(b) and 35(c) minutes ground sample

99.03% for gold with 73.83% of silver was obtained as compared to 25 and 35 minutes ground samples as shown in table 5 and figure 2. Based on analyzing the results it is concluded that the optimum grinding time for shoughur area complex is 30 minutes.

Agitation cyanidation process for un-roasted samples

The cyanidation process was also applied on un-roasted 30 and 35 minutes ground at dosage of sodium cyanide (NaCN) of 5.33 gram, pH 10.40, CaO of 1.5 gram, and cyanidation time 0, 4, 18, 24, 28, 35, 37, and 39 hours. The products obtained from cyanidation were analyzed by atomic absorption spectrometer. The results are presented in table 6.

Table 6 shows that the grade of gold and silver extracted in ppm for un-roasted samples at cyanidation time of 35 hours and grinding time 30 minutes is 11.82

Table 6. Cyanidation Results for un-roasted samples

Times Hours	Un-Roasted # 1 Grind- ing Time 30 min		Un-Roasted # 2 Grind- ing Time 35 min	
	Au	Ag	Au	Ag
2	0.37	0.057	0.34	B.D.L
4	0.63	0.17	0.70	B.D.L
18	2.08	0.30	1.99	0.025
24	1.88	0.81	2.59	B.D.L
28	7.12	3.63	7.11	B.D.L
30	6.99	2.10	7.33	B.D.L
33	7.82	1.84	7.88	B.D.L
35	11.82	11.48	11.95	11.50
37	9.70	10.39	11.50	2.83

B.D.L= Below determination limit

ppm and 11.48 ppm respectively and for 35 minutes ground sample cyanidation time 35 the maximum assay 11.95 ppm for gold and 11.50 for silver was obtained. After comparisons of table 2 and table 5 results it is concludes that cyanidation process on roasted ore samples give better results as compared to un-roasted ore samples.

CONCLUSIONS

The present research work was focused on agitation cyanidation process for extraction of gold and silver from complex ore of shoughour area district Chitral, Khyber Pakhtunkhwa Pakistan the agitation cyanidation process was carried out on 25, 30 and 35 minutes ground roasted samples and 30 and 30 minutes ground un-roasted samples. The maximum assay of 71.82 ppm of gold with percent extraction/recovery of 99.03 % and 39.93 ppm of silver with 73.83 % was obtained for 30 minutes ground sample as compared to 25 and 30 minutes ground samples at dosage of sodium cyanide (NaCN) of 5.33 gram, pH 10.40, CaO of 1.5 gram, and cyanidation time of 37 hours. The maximum assay of gold and silver extracted for un-roasted samples at cyanidation time of 35 hours and 35 minutes ground sample was 11.95 ppm and 11.50 ppm respectively was obtained. After comparisons of results of roasted samples and un-roasted samples it is concluded that the result obtained from agitation cyanidation process on roasted ore samples was better than un-roasted ore samples.

REFERENCES

1. Directorate General of Mines and Minerals (DGMM), (2005), "Report on Complex Ore of Awrith/Shoghore area, Mineral Development Department, Khyber Pakhtunkhwa" pp. 1-12.
2. Akcil, A., (2002), "First application of cyanidation process in Turkish gold mining and its environmental impacts", *Minerals Engineering*, vol. 15, pp. 695-699.
3. Xianwen Dai, Andrew Simons, Paul Breuer, (2012), "A review of copper cyanide recovery technologies for the cyanidation of copper containing gold ores", *Minerals Engineering*, vol. 25, pp. 1-13.
4. Xie, Dreisinger, F. D. B., (2009), "Use of ferricyanide for gold and silver cyanidation", *transactions of nonferrous metals society of china*, vol. 19, pp. 714-718.
5. Kondos, P.D., Deschenes, G., Morrison, R.M., (2009), "Use of ferricyanide for gold and silver cyanidation", *Transaction of nonferrous Metals Society of China*, vol.19, pp. 714-718.
6. Andrade Lima, L.R.P., Hodouin, D., (2006), "Analysis of the gold recovery profile through a cyanidation plant", *International Journal of Mineral Processing*, vol. 80, pp. 15-26.
7. Senanayake, G., (2008), "A review of effects of silver, lead, sulfide and carbonaceous matter on gold cyanidation and mechanistic interpretation", *Hydrometallurgy*, vol. 90, pp. 46-73.
8. Ubaldin S., Vegli F., Toro L., Abbruzzese, C., (1997), "Biooxidation of arsenopyrite to improve gold cyanidation: study of some parameters and comparison with grinding", *International Journal of Mineral Processing*, vol. 52, pp. 65-80.
9. Habashi, F., (1992), "One hundred years of cyanidation", *CIM Bulletin*, vol. 80, pp. 108-114.
10. Marsden, J. H. I., (1992), "The Chemistry of Gold Extraction", *Ellis Horwood*, pp. 34-44.
11. Karimi, P., Abdollahi, H., Amini, A., Noaparaz, M., Shafaei, S.Z., Habashi, F., (2010), "Cyanidation of gold ores containing copper, silver, lead, arsenic and antimony", *International Journal of Mineral Processing*, vol. 95, pp. 68-77.
12. Kondos, P.D., Deschenes, G., Morrison, R.M., (1995), "Process optimization studies in gold cyanidation", *Hydrometallurgy*, vol. 39, pp. 235-250.
13. Weichselbaum, J., Tumilty, J.A., Schmidt, C.G., (1989), "The effect of sulfide and lead on the rate of gold cyanidation in Australia", *IMM Annual Conference, Australia*, pp. 23-33.
14. Roshan, B., (1990), "Hydrometallurgical processing of precious metal ores", *Mineral Processing and Extractive Metallurgy*, vol. 6, pp. 67-80.
15. Dunn, J. C. A., (1997), "The recovery of gold from refractory arsenopyrite concentrates by pyrolysis-oxidation", *Minerals Engineering*, vol. 10, pp. 919-928.
16. Celep, O., Alp, I., Deveci, H., Vicil, M., (2009), "Characterization of refractory behaviour of complex gold/silver ore by diagnostic leaching", *Transactions of Nonferrous Metals Society of China*, vol. 19, pp. 707-713.