

The Efficiency of Amalgamation and Cyanidation for the Extraction of Placer Gold Deposits of Indus River Basin along Gilgit to Thalachi (Gilgit-Baltistan)

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Abstract: Separation of gold from placers are not given importance in Pakistan, but in the economy of Gilgit-Baltistan, it plays a vital role. The study mainly focused on shaking table technique for the extraction of gold from placer deposits along Gilgit river between Gilgit and Thalachi, near Gilgit and Astore river junction. For the separation of gold, from the concentration of shaking table the Hg; mercury amalgamation has been used for it. In the result of the amalgamation process recovered gold was 27.12%. The cyanidation process was used to separate from remains of mercury amalgamation, tailing and middling of shaking table. The graphical results of gold extraction with bottle roll cyanidation and agitation method were compared. The results of gold separation using bottle roll cyanidation and agitation methods were about 87.5% and 29.8% respectively. It is clear from the results, the bottle roll cyanidation is a better technique for the separation of fine gold from placers along with downstream waterway areas, where placer deposits occur.

Keywords: Gold, Gilgit-Baltistan, shaking table; amalgamation; cyanidation.

Introduction

Currently, placer deposits gold extraction is continually decreasing as compared to contributed its proportion to the total quantity of gold mined. However, in the middle of the 19th Century, around 90% of the total mined gold came from placer gold extraction worldwide, except Russia. However, towards the end of the 19th century, it decreased by about 50%. Similarly, in the first decade of the 20th Century 5-20%, as well as towards the end of the 20th Century, it was 10-15%, and at the moment only a few percents (Talgamer, 2017). The main reason for this decrease in placer gold extraction is the resources depletion, climatic conditions and difficulties in the way of their exploitation. There are practically no new placer deposits having a favorable mode occurrence and high content of the valued component. Newly developing placer deposits are usually located in remote regions with harsh or permafrost climate and are characterized by deep occurrence mode of producing layer, high clay or till content, or low content of the valued component.

Historically, the significant portion of gold was extracted from placer deposits, where gold has settled in the downstream waterway areas due to sedimentation from rock outcrops. Few people also used an early form of hard rock mining techniques, digging solid veins of rock for extraction of gold, where water sedimentation had deposited gold since thousands of the years ago. Similarly, the upper Indus basin Pakistan are well known for the occurrence and mining of placer gold. The extraction of gold by gold

finders use indigenous knowledge and tools for separation of gold from deposits (placer) since long period along Indus river basin, Pakistan.

The mineral industry contributes a significant portion of the economy of Gilgit-Baltistan's. The practice of gold washing processes is continued for a long period along the rivers (Gilgit, Hunza and Indus) of northern Pakistan. Currently, about 200 families are involved in the mining process of gold extraction from placer deposits along river Gilgit, Hunza, Indus and Astore using traditional panning technique with mercury (Shah and Khan, 2004). The coarse, fine and ultrafine gold is separated from the deposition of upper Indus river system. The remaining heavy metals and invisible gold are thrown into the river with mercury, which is causing freshwater pollution.

Austromineral (1976) reported the existence of placer gold along the river beds of Gilgit-Baltistan. The technique of amalgamation used for gold separation from placer gold, and more than 10 million people in 50 countries around the world are applying it (Veiga et al., 2006). Gold is usually extracted by a technique of physical and chemical processing (Wills and Finch, 2015). It was studied by Steadman (2013) that placer gold can be extracted by using corn starch, but the chemistry of this process is complex (Steadman, 2013). According to Bamzai and Shukla (1999), the substitutes of placer gold are bromine leaching, chlorination, thiocyanate leaching, thiourea leaching and selenic acid. Ojeda et al. (2009) studied the extraction of gold using chlorine and obtained the best recovery of 98.23% at 873 k and 3600s. The mercury-

free techniques are environmentally friendly but are highly expensive (Hylander, 2001). The gravity separation method is more suitable for separation of placer gold followed by mercury amalgamation method (Shah and Khan, 2004). The amalgamation is very useful for the separation of gold particles whose size is larger than 70µm, while for separation of finer gold particles cyanidation is a suitable technique (Ali, 2015). It is reported that the process of shaking table is the highly reliable approach based on gravity for separation of fine-grained gold bases of specific gravity (Mitchell, 1997). The extraction of more elegant gold of upto 100 µm is done by using a shaking table (Wills and Finch, 2015). Mercury amalgamation method was used to separate from coarse-grained concentrates and cyanidation process was used for separation of fine-grained gold concentrates (Hylander et al., 2007). The main objective of the study was to search and mining of gold and determine the efficiency and suitability of amalgamation and cyanidation method for the separation of gold from placers along the Gilgit river (Upper Indus Basin, Pakistan) side from Gilgit to Thalichi (Diamer).

Study Area

Gilgit-Baltistan of Pakistan comprising of high peaks of Himalaya, Karakoram and the Hindu Kush, on the north side and those of western Himalayas on the southern side is providing the mysterious far-off land preserving the ancient of human traditions in association with mountain fairies. GB is located in north edge of Pakistan bordering with China, India and Afghanistan internationally, on north (35° 37' 00" N) and East (72° 75' 00" E) covers an area of 72,496 km² (27,799 square miles) with elevation varying between 1000m and 8,611 m ASL. Major land uses glaciers (28.7%, n=72496 km²), agricultural land (1.36 %), forests (3.2 %), rangelands (32 %), barren lands i.e., rocks, clips and bare soils (34.4 %) and others including streams and rivers (0.43 %) of total area (Khan, 2013). Geographically, climatically, geologically, and biologically the area represents a land of trans-Himalayan character, where monsoon rain and seasons of the plain are almost totally absent.

Geology of the study area includes Gilgit Formation, Jaglot syncline, enclosing younger strata of the Gashu-confluence volcanic and Thelichi Formation. According to the mapping of Khan et al. (1994), Gilgit Formation consists of normally interstratified at regular intervals of paragneisses and schists, which are metapsammities and metapelites and their trend in NW-SE direction with steep dip either towards north or south and reach nearly 1 km thickness. These rocks are exposed in the vicinity of Gilgit between Jagalot and Gilgit along the Karakoram highway (KKH), which includes Kargah, Jutial, Skawar, Minwar, and Sai Nallahs. Different type of rocks encompassing the Gilgit Formation are the amphibolites and calc-silicate rocks and distribution of the Gilgit Formation is

structurally controlled (Khan et al., 1994). Thelichi Formation is approximately covered by the Gashu-confluence volcanics, in which the lower contact is not clear, but seemingly under-platted by the Chilas Complex (Khan et al., 1994).

Materials and Methods

For the separation of gold from placer deposits, about 256 tons were collected from 23 different locations of the study area with Global Positioning System (GPS) points during the field of study using with standard sampling method (ASTM D-6883). The detailed field study was conducted to ensure the availability of minerals, their grain size and other characteristics to choose suitable and economical techniques for separation of sedimentary gold from placers (Fig 2). Benching and pitting technique was used to scan the entire study extent for sampling. Stand seats were cut from the river banks and the collected samples were used as input to the pneumatic machine for the measurement of concentrate of the material. About 500kg refined material separated from 256 tons and were sent to Peshawar Mineral Testing Laboratory (MTL) for further laboratory analysis. The main aim of the laboratory analysis to measure the concentration of gold and silver on laboratory scale for the separation.

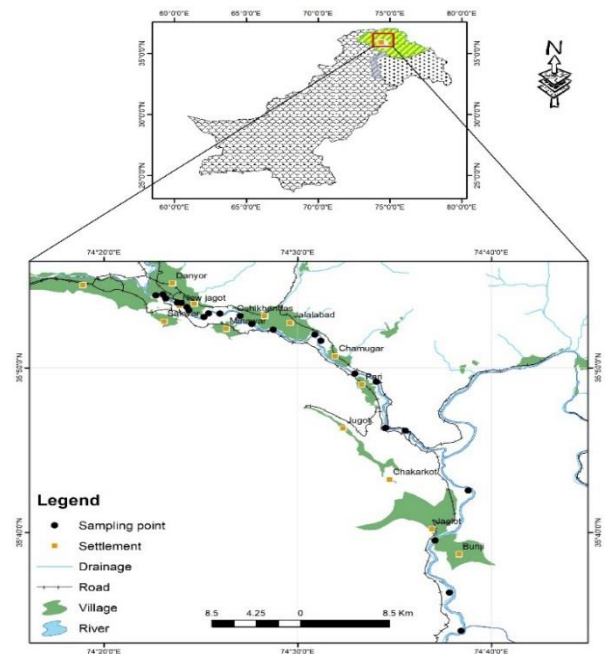


Fig. 1 Map of the study area with sampling points along the Gilgit River (between Gilgit and Thalachi).

The dried and weighed samples were further analysed and sifted to eliminate the coarse particles/material from the sample purification. However, the whole material was put regularly into more split from the top; which is randomly divided into two equal sized portions with a fraction of 1/4, 1/8/. The tested samples were packed into the sample's bags for further laboratory examination. Sieved substantial was across via a shaking table, which separated different three

types of ingredients such as middling, tailing and concentrate materials. The thicker portion of the sample separated as a concentrate, materials with less solid particles comparative to concentrate was distinguished as middling, and the remaining was calm as tailing.



Fig. 2 Field picture showing process of placer gold extraction with shaking table and pan.

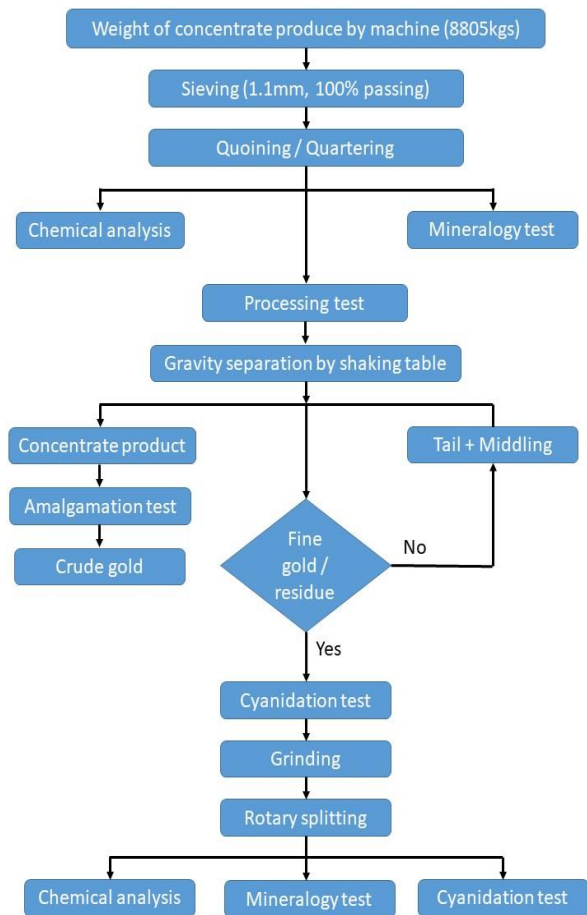


Fig. 3 Data flow diagram (process of gold extraction with Amalgamation and cyanidation).

The concentrate of the shaking table was installed on the ground — the rotating of the disk of the machine (flotation) in the existence of water. For the exposition of course gold, the substances (lime and mercury) were added into samples and shaking continued of the bottle

rolling mill for 20 minutes. The amalgamated mercury (pregnant) holding gold is separated from the strenuous samples by used panning/mercury amalgamated technique with an iron retort. The mercury amalgamated process segregated from the raw samples (concentrated) holding gold. Later, it is heated about 700 °C in the retort furnace. This process burns the mercury and detached gold from crude gold (mercury amalgamated) and put in the suction vessel for condensing in the availability of water, for further processing. The residue of (amalgamated mercury) substantial is treated with cyanidation process to examine the presence of any gold, which separated copper (Cu) and silver (Ag).

The process of middling gravity parting and the rest of the processed samples (mercury amalgamation) were mixed to make a uniform substance sample. The portion from the bulk samples, about one kg has been collected from agitation/cyanidation for further leaching test. Further, another one kg representative sample has been collected for bottle-roll cyanidation test. Furthermore, both the samples were transformed into pulp by an added of tap water and lime (a known quantity) to increased its pH value up to 10.5%, and about 0.1% NaCN was added in the solid solution for further processing. During the process of cyanidation, collective samples of pregnant solution gathered after a different interval (2, 18 and 24 hours) from agitation cyanidation and also from bottle cyanidation respectively.

Furthermore, collected representative samples of different intervals were analysed by atomic absorption system for the determination of the gold and silver particles/substances recovered from it. After completion of the cyanidation test, the pulp was sieved, and the filtered materials were carefully washed to confirm the change of entire gold and silver into the prenatal solution. These residues sampled solutions were put for drying and fire examine technique was applied to it for analyses the gold and silver extraction if remain any. The total time/duration required for the separation/extraction of gold and silver as well as for the mixture analysis (cyanidation test experiments) were also determined. The comparison of the two processes (agitation and bottle roll) were also analysed for the suitability of the process for gold and silver separation (extraction) from deposits of placer gold (Fig. 3).

Results and Discussion

The extraction of gold from placer gold along the Gilgit river from Gilgit-Thalechi shows impressive results. Results indicated that the bottle roll cyanidation method is more suitable technique as compared to agitation method for extraction of fine gold from placer deposits in the downstream waterway areas. The method of bottle roll cyanidation and agitation methods were applied on 256 tons of original material and later it was refined and 500kg gold (Au)

bearing concentrate was extracted using Pneumatic machine.

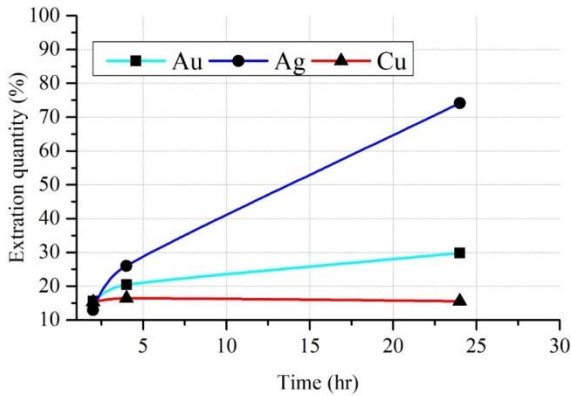


Fig. 4 Extraction of gold in quantity with time relationship by agitation method.

From the chemical analysis of the original head sample and shaking table elements founded 1.9 gm/ton, <0.05gm/ton and 30 gm/ton in Au, Ag and Cu respectively, (Table 1). Table 2 represented laboratory experiments results of shaking table with the concentrate of 80 gm/ton, 6gm/ton and 120gm/ton in Au, Ag and Cu respectively, and similarly middling 10, 0.6, <0.5 grams per tons respectively for Au, Ag and Cu.

Table 1. Chemical analysis of the original head sample.

Chemical analyses of head sample	
Au	1.90 g/t
Ag	<0.05gm/ton
Cu	30gm/ton

A total of 54.499 kg feed material was processed by the shaking table. The details of concentrate, middling and tailing are shown in Table 2. Column C represented the extraction of physical gold by amalgamation process. The study results represented

Table 2. Laboratory experiments of shaking table.

Product detail	Weight (kg)	Recovery (%)	Au (gm/ton)	Ag (gm/ton)	Cu (gm/ton)
A	B	C	D	E	F
Concentrate	1.9	3.55	80	6	120
Middling	5.35	10	0.6	<0.5	31
Tail-1	12.76	23.85	0.54	<0.5	45
Tail-2	33.489	62.6	0.5	<0.5	27
Total	53.499	100			

Figure 4 showed the extraction of gold by agitation cyanidation method. It was detected that the capturing of gold increased sharply with increase in time. The maximum recovery of gold was 29.8 % after 24 hours. It was also observed that the difference in the recovery of Au, Ag and Cu increased with increasing time. Better separation of Ag was observed in agitation method, but the recovery of gold is minimum. The agitation cyanidation method showed a sharp separation between Au, Ag and Cu with a relatively low extraction.

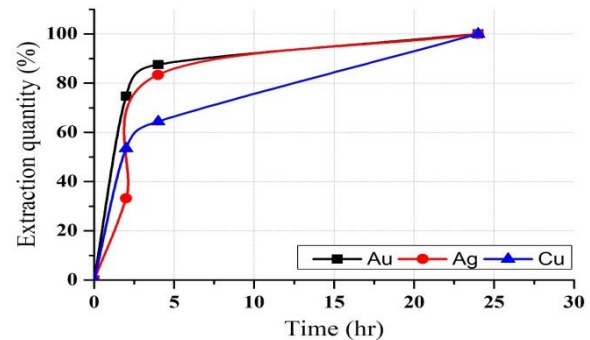


Fig. 5 Extraction of gold by bottle rolling method relationship with time.

Figure 5 represented the extraction of gold from placer deposit with bottle roll cyanidation method. About 87.55% gold and 83.40% silver were extracted from processed samples respectively as compared to the mercury amalgamation technique, which was about 27.12% for gold separation. Extraction of gold (88%), copper (83%) and mercury (63%) increased rapidly up to 5 hours in the practice of bottle rolling method.

Table 3. Agitation cyanide leaching test.

Time (Hr.)	Contents and Additions				Solutions					
	Solid	Water	NaCN	CaO	NaCN	pH	pH	Au	Ag	Cu
	(g)	(g)	(g)	(g)	%	Pre	Post	g/ton	g/ton	g/ton
0	1000	1000	1	5	0.1	7.8	10.50	-	-	-
2	-	-	0.73	2	.027	9.36	10.49	10	1	15
4	-	-	0.66	2	.035	10.02	10.60	13	2	16
24	-	-	0.66	-	.035	10.40	10.05	20	6	16

the process of gold extraction with amalgamation process, however extracted quantity of gold concentration is negligible. Therefore, it is necessary to modify process for further better results for extraction of gold. Similarly, the agitation and bottle roll cyanidation are given in Table 3, 4.

After 5 hours there was a gradual increase of extraction up to 24 hours which reached 100% each respectively. Extraction of gold is maximum after 24 hours. Furthermore, the maximum Cu, Au and Ag were extracted using bottle roll cyanidation method through the processing of fine and ultra-fine particles.

Table 4. The Bottle Role Cyanide Leaching Test results.

Time (Hr)	Contents and Additions				Solutions						
	Solid (g)	Water (g)	NaCN (g)	CaO (g)	%	NaCN Pre	pH Post	pH g/ton	Au g/ton	Ag g/ton Adjust.	Cu Adjust.
0	1000	1000	1	4	0.1	70.5	11.0	-	-	-	-
2	-	-	0.69	1.3	0.031	10.65	11.0	18	2	15	
4	-	-	0.49	1	0.051	10.70	10.6	21	5	18	
24	-	-	0.55	-	0.045	10.60	-	N/A	N/A	N/A	

Conclusion

The study examines the gold extraction from placer deposits along the Gilgit river (upper Indus basin, Pakistan) in between Gilgit and Thalichi (Diamer) with two different methods namely amalgamation and bottle roll cyanidation methods, and also calculated their efficiency and suitability for extraction of gold from placer deposits. The results revealed that the separation of gold with bottle roll cyanidation method (88%) is more suitable as compared to amalgamation (27%). The method of cyanide was used to separate fine gold from the scum of amalgamation (mercury), tailing and middling of shaking table. The graphic result of gold extraction with bottle roll cyanidation and agitation was compared with the help of chemical tests. The bottle roll cyanidation is a better choice for the mining of gold from placer deposits along river beds of downstream areas.

In the light of the above results, evaluation criteria and discussion, conclusion is given below.

- The bottle roll cyanidation results showed high efficiency for gold extraction from placer deposits.
- The study also suggested that amalgamation is only suitable for coarse-fine particles.
- The fine and ultra-fine gold particles can be extracted using cyanide technique, which is a better option for extraction of fine gold rather than agitation cyanidation.

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