Obtaining of Gold from Slovak Concentrate by Using an Innovative Method

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Abstract

The complicated processing of concentrates with low gold content and the long-time use of non-ecological methods was the motion for finding a more efficient process for this noble metal obtaining. From this point of view, this research was focused on obtaining of nano gold from the concentrate White Hill (Detva, Slovakia) using mechanical activation and mechano-biological activation in a molecular hydrogen solution. Gold in this complex concentrate occurs physically enclosed in the intercrystalline space of minerals and is also isomorphic and fills defects in their structure. The exclusion of gold from such complex mineral matrixes of the concentrate can be achieved using a mechano-biological process. This innovative method for obtaining of nano gold with the application of a molecular hydrogen solution is an advantageous alternative to the non-environmental reagents used. Compared to the most used worldwide toxic cyanide reagent, a solution with molecular hydrogen represents a low-cost and above all completely harmless reagent with very good kinetics. Mechanical processes use high-energy milling, which has an effect on the more intensive formation of surface and bulk defects in solid substances. The main advantage of mechanical processes is a smaller number of technological operations, a shorter time required to obtain the desired product at favorable environmental temperatures, and also the formation of nanostructures. The use of a biological process with the application of limnetic algae showed that algae with siliceous structures make it possible to obtain gold from the White Hill concentrate with nanoscale size. Limnetic algae (diatoms, golden algae) are part of aquatic ecosystems and create the largest matter of biomass from all plants on the Earth. The mechano-biological process is a method that enabled to obtain of gold nanoparticles with an average size of 100 nm from the Slovak gold-bearing concentrate from the White Hill deposit (BV-1). Mechanical activation of this concentrate and siliceous shells of the specified limnetic algae (Dinobryon, Surirella) in a molecular hydrogen solution caused changes in the physical-chemical properties of gold minerals as well as in the constituents of algae minerals. These structural changes had a decisive influence on the exclusion of gold nanoparticles into the molecular hydrogen solution under the defined reaction conditions. The gold nanoparticles were subsequently fixed in the cellular matrix of mechanically activated algae shells. The explanation of this phenomenon was the action of biomolecules, which the algae cells secreted in the course of reactions with metal ions present in the molecular hydrogen solution. Gold nanoparticles from the investigated concentrate were obtained by a new mechano-biological procedure already for four hours. In the case of mechanical activation of the concentrate, but without activation of the used algae, gold nanoparticles were excluded after sixteen hours. It follows from this knowledge that the application of an absolutely ecologically harmless aqueous solution enriched by molecular hydrogen and the use of limnetic algae confirmed the suitability of the innovative method for obtaining of nano gold from the concentrate. From the achieved research results significantly more effective kinetics is evident in the case of activated algae. Nanoparticles of gold obtained by the mentioned procedure can have important practical utilization, such as accelerating of the decomposition of dangerous substances or neutralizing pollutants in contaminated water, soil, and air. Simultaneously, obtaining of gold nanoparticles would also be beneficial for removing algae from the aquatic environment, where they are very dangerous for all living organisms.

Keywords: gold, algae, molecular hydrogen, mechanical activation

Introduction

Since the dawn of civilization, minerals and metals have played an irreplaceable role in the progress of mankind. Their gradual predominance in human life over time is obvious and without them no nation can develop. The limitations of conventional metal mining processes, the continuous decline of mineral raw materials in terms of quality and quantity, the reduction of the availability of new sources of minerals, as well as the increased awareness of environmental pollution and its effects have forced planners for a better use of available resources for future humanity, to look for an alternative way of obtaining metals from complex concentrates using an ecological procedure.

One of the ecologically innovative methods for obtaining gold from complex concentrates is the mechano-biological process. The mechano-biological method is a simple, effectively clean and economically viable innovative procedure. This method can be described as the extraction of gold nanoparticles from gold-bearing concentrates using the action of algae [1, 2]. The physical pre-treatment of concentrates is carried out in intensive milling equipment, in which they are the mechanical activation [3].

The processing of secondary raw materials with a low gold content is in the center of attention of all developed economies of the world, with great emphasis on environmental protection. Recovering gold and reducing the environmental burden through recycling requires a comprehensive strategy and in particular the use of cyanide-free methods. Cyanidation is toxic and, moreover, highly demanding in the case of gold-bearing concentrates. Gold in concentrates is mainly found in a finely dispersed form and for this reason cannot establish contact with toxic cyanides. However, the release of gold nanoparticles from complex mineral matrices of concentrates can be achieved using an ecological mechano-biological procedure. This innovative procedure for obtaining nano gold from concentrates with the application of a solution with molecular hydrogen is an advantageous alternative to the toxic methods used. Molecular hydrogen represents an ecologically acceptable agent with extraordinary kinetics and efficiency.

Mechanical processes use high-energy milling and intensify processes by creating surface and volume defects in solids. The main advantage of mechanical processes compared to traditional technologies is the significantly shorter time required to obtain the required metal at favorable ambient temperatures and, above all, the formation of nanostructures.

The biological method using freshwater algae with silicate casings in mechanical processes is considered an environmental and effective method of obtaining gold from difficult-to-process gold-bearing concentrates [4].

The presented innovative study is focused on the application of a mechano-biological process, which makes it possible to obtain gold nanoparticles from the complex concentrate White Hill (Detva, Slovakia).

Experiments

Methodology

Chemical analysis of samples was performed using a 240FS / 240Z atomic absorption spectrometer (Varian, Australia). Mechanical and mechano-biological activation of samples was performed using LME 0.75 (Netzsch, Germany) high-energy laboratory stirrer mill. To characterize the surface properties of the samples was used apparatus NOVA 1200e (Quantachrome Instruments, USA). The morphology of samples was studied by scanning electron microscopy using EDX-FE SEM MIRA 3 method (TESCAN, Czech Republic). To measure the particle size distribution in the nanometer region was used laser granulometry (Nanophox Sympatec GmbH, Germany). The amorphization of the samples was evaluated by the X-ray diffractometry method.

Mechano-Biological Activation

The mechano-biological activation was carried out in an Attritor Molinex LME 0.75 (Netzsch, Germany) high-energy laboratory stirrer mill, with a milling chamber volume of 500 ml. Steel balls of 2000 g with a diameter of 2 mm were used as the milling medium. A sample of White Hill concentrate (Detva, Slovakia) 50 g was milled with siliceous shells of limnetic algae of the genera Dinobryon / Surirella (Třeboň, Czech Republic) 2 g in a solution of molecular hydrogen as a leaching medium of 200 ml. The mill was operated at a milling shaft speed of 600 min^{-1} during the grinding time of 4-16 hours at ambient temperature. An Edenlive Mysuso generator with a volume of 1.5 l was used for the preparation solution of molecular hydrogen.

Results And Discussions

Complex concentrate White Hill (Detva, Slovakia) was selected as input material for the testing acquirement of gold with the utilization of algae in mechanical processes. The chemical composition of this concentrate is presented in Table 1.

The mineralogical composition of the used concentrate is of primary importance. During the bio-oxidation of minerals, various toxic substances are leached that are often naturally present in minerals and have been found to inhibit the binding of gold to the silicate shells of algae. The adverse effects that these inhibitors have on the algae probably result in a lower rate of mineral oxidation. The porosity of the mineral particles of the concentrate, as well as the algae shell particles, is responsible for the penetration. An important aspect of the investigated metal extraction is the contact mechanism, so the surface plays an important role. The leaching activity of nano gold is proportional to the available surface of the samples. Reducing the particle size means increasing the total surface area of the particles, so a higher yield of nano gold can be obtained without any change in the total weight of the particles. A particle size of around 100 nm is considered optimal for mechanical activation. The mechanical activation of the complex concentrate in the Attritor mill is characterized by an increase in the specific surface area. The effect of milling on the surface area of the concentrate is summarized in Table 2. The original value of the surface area (0.24 m^2g^{-1}) increased to 4.8 m^2g^{-1} without the use of algae. In the case of using Dinobryon/Surirella algae, they measured significantly higher surface area values of 12.4 m^2g^{-1} and 16.2 m^2g^{-1}.

Tab. 1. Chemical composition of the complex concentrate White Hill (Detva, Slovakia).

Components [gt^{-1}]		**Components [%]**							
Au	Ag	Cu	Pb	Zn	Fe	Sb	As	S	SiO_2
124	148	18.9	4.2	12.3	24.6	4.7	2.9	1.4	28.6

Tab 2. Specific surface area, SA for samples of concentrate White Hill (Detva, Slovakia): non-activated, mechanically activated (MA), and mechanically activated (MA)/type of algae.

Samples	**S_A [m^2 g^{-1}]**
Non-activated concentrate	0.24
MA concentrate	4.8
MA concetrate/Dinobryon	12.4
MA concetrate/Surirella	16.2

The milling in stirred ball mill led to the amorphization of the gold-bearing minerals present in the concentrate, which decompose following of mechanical process with the utilization of algae to set nano gold free in the solution of molecular hydrogen. The significant change due to intensive milling was the increase of the input value of the amorphization of the non-activated concentrate to 48 % without the use of algae (Table 3). In the case of the use of algae, Dinobryon/Surirella in the mechanical process was measured the considerably higher values of amorphization 86 to 94 %.

Tab. 3. Amorphization, A for samples of concentrate White Hill (Detva, Slovakia): non-activated, mechanically activated (MA), and mechanically activated (MA)/type of algae.

Samples	**A [%]**
Non-activated concentrate	0
MA concentrate	48
MA concetrate/Dinobryon	86
MA koncentráte/Surirella	94

Mechanical activation of complex concentrate White Hill (Detva, Slovakia) and siliceous shells of specified limnetic algae of genera (Dinobryon, Surirella) in the molecular hydrogen solution caused changes in the physico-chemical properties of gold minerals as well as algae mineral constituents. These structural changes had a decisive influence on the formation of gold nanoparticles (100 nm) into molecular hydrogen solution under the specific reaction conditions mentioned above, from which they were subsequently fixed in the cellular matrix of mechanically activated algal shells. The cause of the formation of gold nanoparticles was the action of biomolecules that algal cells secrete while they defend against the chemical effect of metal ions present in the solution. In the case of the leaching in molecular hydrogen of activated concentrate the and presence of non-activated algae, nanoparticles of gold were obtained during 16 hours (Figures 1a, 2a). Nanoparticles of gold were obtained during 4 hours by described the mechanico-biological process during activating the concentrate and algae at the same time (Figures 1b, 2b).

The results showed that the mechano-biological method for obtaining gold has a great economic advantage, because this process has low capital and energy costs, shows high flexibility, and does not pollute the environment. In general, bioprocesses alone account for one-third to one-half the cost of conventional chemical and physical technologies.

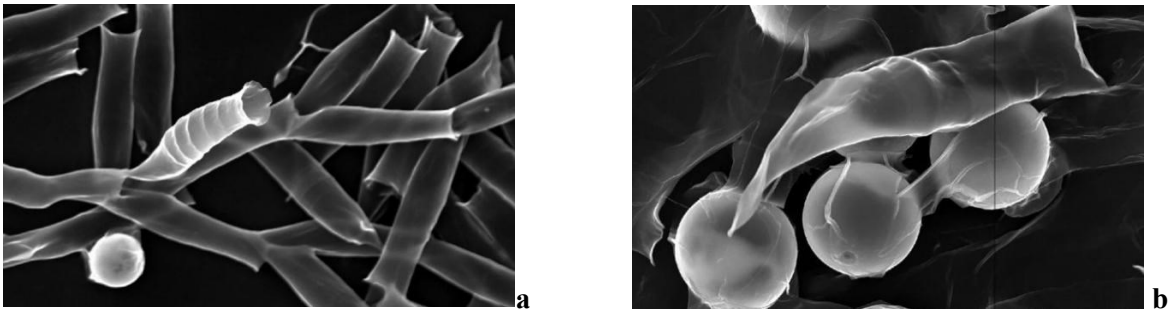

Fig. 1. SEM micrograph of the: a) - non-activated sample algae Dinobryon and activated sample concentrate, b) - mechanically activated sample (concentrate and algae Dinobryon), gold nanoparticles attached in algal cells.

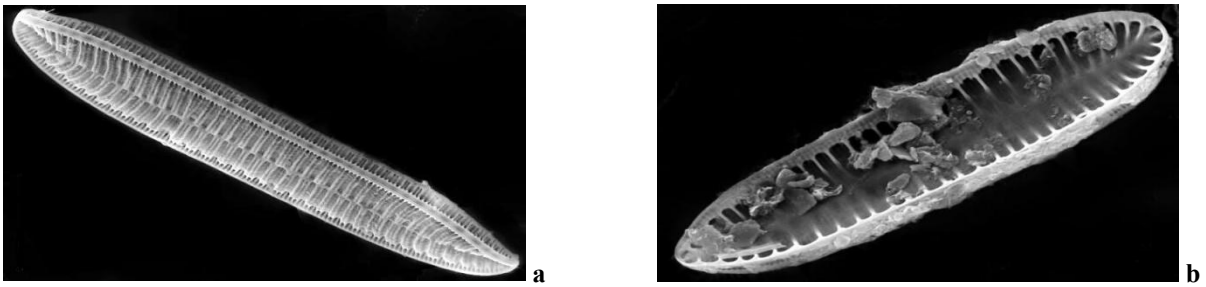

Fig. 2. SEM micrograph of the: a) - non-activated sample algae Surirella and activated sample concentrate, b) - mechanically activated sample (concentrate and algae Surirella), gold nanoparticles attached in algal cells.

Conclusions

The processing of noble metal concentrates involves many complex operations, some of which produce solid, aqueous, and gaseous pollutants that need to be properly managed to prevent environmental degradation. Their processing almost always affects the natural aquatic environment, and its effects can be felt throughout the life cycle of secondary sources of precious metals.

Biotechnologies offer many advantages over conventional technologies, especially in the use of mechanical-biological activation with the application of limnetic algae and molecular hydrogen. Molecular hydrogen is a completely harmless leaching agent with excellent beneficial effects for leaching nano gold from complex concentrates. Limnetic algae are easily adaptable, are not very dependent on the quality of the concentrate, and are self-sustaining. The end result is the presented innovative process that can process refractory concentrate with interesting gold content at low costs and is environmentally friendly. Additionally, algae systems generally operate at ambient pressure and ambient temperature, making them safer. Biological systems are natural and have evolved over many years to perform their role effectively. The mentioned innovative method can help to clean water sites and at the same time, the company will be profitable. For example, such an aqueous environment with algae Dinobryon and Surirella from the site (Třeboň, Czech Republic) is shown in Figures 3 and 4.

Fig. 3. The aquatic environment with algae Dinobryon (Třeboň, Czech Republic).

Fig. 4. The aquatic environment with algae Surirella (Třeboň, Czech Republic

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