



# Obtaining of Nano Gold from Concentrate (Banská Hodruša, Slovakia) using Algae with Utilization of Mechanochemical Activation

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**Abstract-** The difficult and predominantly toxic processing of sulphide concentrates with a low gold content has prompted the finding of a more efficient and environmentally friendly method of obtaining this noble metal. This work was therefore focused on the recovery of gold from the concentrate of refractory sulphide complex (Banská Hodruša, Slovakia) using a non-cyanide mechanochemico-biological process. Gold in this complex concentrate is physically located in the intercrystalline space of sulfide minerals and fills in structural defects in sulfides. The precipitation of gold from the complex mineral matrices of the concentrate can be achieved using a mechanochemico-biological process. This innovative process makes it possible to recover gold by applying a thiourea solution, which is a preferred alternative to toxic cyanidation. The use of a biological process with the application of algae has shown that algae with siliceous structures make it possible to obtain gold from a complex concentrate (Banská Hodruša, Slovakia) with dimensions of the nano. Limnetic algae (diatoms, golden algae) are part of aquatic ecosystems and form the largest of biomass of all plants on Earth. Mechanochemicobiological process is a method that allows to obtain 100 nm gold nanoparticles from refractory sulphide concentrate (Banská Hodruša, Slovakia).

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# Obtaining of Nano Gold from Concentrate (Banská Hodruša, Slovakia) using Algae with Utilization of Mechanochemical Activation

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**Abstract-** The difficult and predominantly toxic processing of sulphide concentrates with a low gold content has prompted the finding of a more efficient and environmentally friendly method of obtaining this noble metal. This work was therefore focused on the recovery of gold from the concentrate of refractory sulphide complex (Banská Hodruša, Slovakia) using a non-cyanide mechanochemico-biological process. Gold in this complex concentrate is physically located in the intercrystalline space of sulfide minerals and fills in structural defects in sulfides. The precipitation of gold from the complex mineral matrices of the concentrate can be achieved using a mechanochemico-biological process. This innovative process makes it possible to recover gold by applying a thiourea solution, which is a preferred alternative to toxic cyanidation. The use of a biological process with the application of algae has shown that algae with siliceous structures make it possible to obtain gold from a complex concentrate (Banská Hodruša, Slovakia) with dimensions of the nano. Limnetic algae (diatoms, golden algae) are part of aquatic ecosystems and form the largest of biomass of all plants on Earth. Mechanochemicobiological process is a method that allows to obtain 100 nm gold nanoparticles from refractory sulphide concentrate (Banská Hodruša, Slovakia). The mechanochemical activation of this concentrate and the siliceous shells of limnetic algae strains (*Dinobryon*, *Surirella*) in thiourea solution caused changes in the physicochemical properties of gold minerals as well as in their components. These structural changes, under specific conditions, had a decisive influence on the precipitation of gold nanoparticles into the thiourea solution. The gold nanoparticles were then fixed in a cell matrix on mechanochemically activated algal shells. The reason for the fixation of the gold nanoparticles was the action of biomolecules, which secreted algal cells during activation, while again preventing the chemical effect of metal ions present in the solution. Gold nanoparticles were obtained from the concentrate after less than one hour by the described mechanochemico-biological process. In the case of mechanochemical activation of the concentrate, but without activation of defined algae, the exclusion of gold nanoparticles was not even during of six hours. That was the reason, the algae had to be activated by milling to obtain gold from this sulfide concentrate.

**Keywords:** gold, concentrate, algae, mechanochemical activation.

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## I. INTRODUCTION

Obtaining of the gold from secondary raw materials with reducing the environmental load by recycling requires a specific strategy and the use of non cyanide methods. The cyanidation is indeed highly toxic and disadvantageous because the gold in the secondary sources is finely dispersed and cannot come into contact with the cyanide solutions. A very serious problem is also of liquidation of cyanide solutions. These justified reasons should be global avoided the use of cyanide technologies in obtaining gold.

However, the release of gold from complex mineral matrixes of sulphide concentrates is possible to achieve by the application of mechanochemicobiological processes [1,2]. The non-cyanide hydrometallurgical process of obtaining gold from concentrates by thiourea solutions is a preferred alternative to the toxic cyanidation method [3]. The thiourea compared to cyanide represents an ecologically acceptable leaching agent with exceptional kinetics and selectivity. Mechanochemical processes utilize highenergy milling and intensify processes through the formation of various surface and volume defects in solids. The main advantage of mechanochemical processes compared to traditional technologies is the smaller number of technological operations, the considerably shorter time required to obtain the desired product at favorable ambient temperatures, as well as the formation of nanostructures [4].

The biological method by using of freshwater algae with silicate shells in mechanochemical processes is considered to be a more environmentally friendly and efficient method than toxic cyanidation to recover gold from refractory sulphides of gold-bearing concentrates [5,6]. Presented innovative study is focused on the application of mechanochemico-biological process enables to obtain gold nanoparticles from the refractory sulphide concentrate (Banská Hodruša, Slovakia). Mechanochemical activation of this concentrate and silica algae shells in thiourea solution increases the number of fine particles with a large specific surface area and some degree of disruption of the mineral components.

Currently present it is a necessity to deal with non-cyanide technologies of gold extraction.

## II. EXPERIMENTS

### a) Methodology

The chemical analysis of the samples was measured on a 240FS/240Z atomic absorption spectrometer (Varian, Australia). The specific surface area SA was determined by the low-temperature nitrogen BET adsorption method using a Gemini 2360 sorption apparatus (Micromeritics, USA). The morphology of the samples was monitored by scanning electron microscopy using EDX-FE method SEM Mira 3 (Tescan, Czech Republic). The particle size distribution was measured by photon cross-correlation spectroscopy using a Nanophox particle size analyzer (Sympatec, Germany). The amorphization of the samples was evaluated by the X-ray diffractometry method.

### b) Mechanochemico-biological activation

Mechanochemico-biological activation was performed in a stirring ball mill Attritor Molinex PE 075

(Netzsch, Germany) with the volume of the milling chamber 500 ml. Sample of sulphide concentrate (Banská Hodruša, Slovakia) 50 g, thiourea as the leaching medium 2 g and siliceous shells of limnetic algae of genera Dinobryon/Surirella (Třeboň, Czech Republic) 2 g together with sulphuric acid (to maintain the pH of the solution = 1) was milled with 200 ml of distilled water and 2000 g steel balls of diameter 2 mm as the milling media. The mill was operated at revolutions of milling shaft 600 min<sup>-1</sup> for milling time 60 min at ambient temperature.

## III. RESULTS AND DISCUSSIONS

Complex sulphide concentrate (Banská Hodruša, Slovakia) was selected as input material for the testing acquirement of gold with the utilization of algae in mechanochemical processes. The chemical composition of this concentrate is presented in Table 1.

Table 1: Chemical composition of the sulphide concentrate ( Banská Hodruša, Slovakia)

Components [ g t <sup>-1</sup> ]		Components [ % ]							
Au	Ag	Cu	Pb	Zn	Fe	Sb	As	S	SiO <sub>2</sub>
329	183	11.5	6.2	9.4	17.9	3.1	12.6	19.8	13.2

The mechanochemical activated of the complex concentrate in the mill Attritor is characterized by an increase in specific surface area. The effect of milling on the surface area of concentrate is summarized in Table 2. The original value of the surface area (0.37 m<sup>2</sup>g<sup>-1</sup>)

increased to 2.8 m<sup>2</sup>g<sup>-1</sup> without the use of algae. In the case of use algae, the Dinobryon/Surirella were measured the significantly higher values of the surface area 9.5 m<sup>2</sup>g<sup>-1</sup> and 12.6 m<sup>2</sup>g<sup>-1</sup>.

Table 2: Specific surface area, SA for samples of concentrate (Banská Hodruša, Slovakia). Non-activated, mechanochemical activated (MA) and mechanochemical activated (MA)/type of algae.

Samples	SA [ m <sup>2</sup> g <sup>-1</sup> ]
Non-activated concentrate	0.37
MA concentrate	2.8
MA concetrates/Dinobryon	9.5
MA concetrates/Surirella	12.6

The milling in stirred ball mill was led to amorphization of the gold-bearing minerals present in the concentrate, which ones decompose following of mechanochemical process with the utilization of algae to set nano gold free in the leach. The significant change after due to intensive milling was increased of

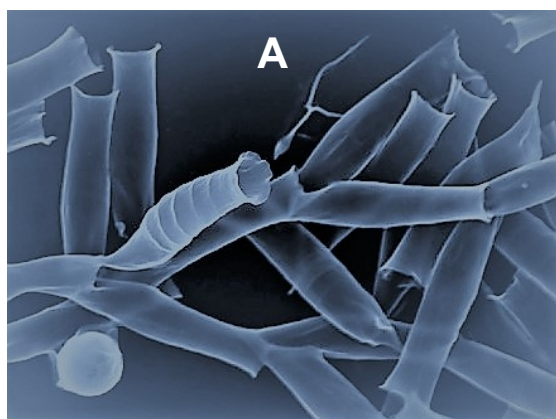
the input value of the amorphization of the non-activated concentrate to 63 % without the use of algae (Table 3). In the case of use algae, Dinobryon/Surirella in the mechanochemical process were measured the considerably higher values of amorphization 86 to 91 %.

**Table 3:** Amorphization, A for samples of concentrate (Banská Hodruša, Slovakia). Non-activated, mechanochemical activated (MA) and mechanochemical activated (MA)/type of algae

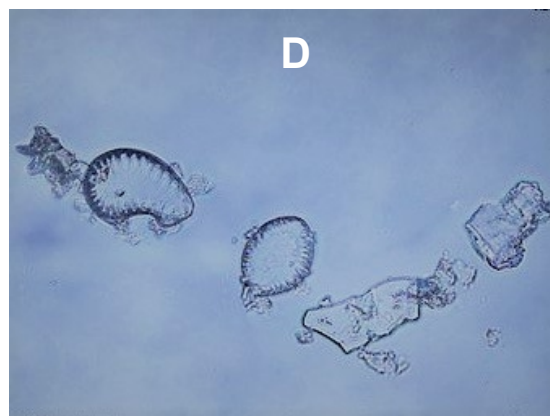
Samples	A [ % ]
Non-activated concentrate	0
MA concentrate	63
MA concentrate/Dinobryon	86
MA concentrate/Surirella	91

Mechanochemical activation of sulphide concentrate (Banská Hodruša, Slovakia) and siliceous shells of specified limnetic algae of genera (Dinobryon, Surirella) in the thiourea 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 thiourea solution under the specific reaction conditions mentioned above, from which they were subsequently fixed in the cellular matrix of mechanochemically 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 thiourea leaching of activated sulphide concentrate in the presence of non-activated algae, no nanoparticles of gold were obtained even after one day (Figures 1A, 2C). Nanoparticles of gold were obtained after fifty minutes by described the mechanochemico-biological process after activating the concentrate and algae at the same time (Figures 1B, 2D).



**Figure 1:** SEM micrograph of the: A - Non-activated sample algae Dinobryon and activated sample sulphide concentrate, B - Mechanochemical activated sample (sulphide concentrate and algae Dinobryon), gold nanoparticles attached in algal cells



**Figure 2:** SEM micrograph of the: C - Non-activated sample algae Surirella and activated sample sulphide concentrate, D - Mechanochemical activated sample (sulphide concentrate and algae Surirella), gold nanoparticles attached in algal cells



#### IV. CONCLUSION

The nanoparticles of gold obtained by the described way may have different uses in practice, such as accelerating the decomposition of hazardous substances or eliminating pollutants in contaminated water, soil, and air. Acquirement nanoparticles of gold through this process would also lead to the elimination of algae from the aquatic environment where they are

dangerous not only for aquatic plants and animals but also for humans. For example, such an aqueous environment with algae *Dinobryon* and *Surirella* from the site (Třeboň, Czech Republic) are shown in Figures 3 and 4. It is generally known that defined algae absorb carbon dioxide and emit oxygen, thus playing an important role in preserving life on Earth.



*Figure 3:* The aquatic environment with algae *Dinobryon* (Třeboň, Czech Republic).



*Figure 4:* The aquatic environment with algae *Surirella* (Třeboň, Czech Republic).

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