

ELECTROKINETIC LEACHING IN GOLD AND SILVER ORES

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ABSTRACT

The application of electrical current to accelerate and direct the movement of metallic ions has been used in the remediation of soils contaminated with heavy metals. In this paper, the feasibility of using electrokinetic principles from soil remediation in a series of column leach tests with a mineral containing gold and silver is evaluated. The variables analyzed in this project were the current, the voltage and the reagent concentration. Preliminary results indicate that it is feasible to use soil remediation technology for increasing the rate of leaching of gold and silver ores.

KEYWORDS: electrokinetic; column leach; gold; silver.

RESUMO

A aplicação de corrente eléctrica para acelerar e dirigir o movimento de iões metálicos foi usado na recuperação de solos contaminados com metais pesados. Este trabalho estudou a viabilidade da utilização de princípios electrocinéticos de descontaminação de solos em uma série de colunas de lixiviação com um mineral contendo ouro e prata. A corrente, tensão e concentração de reagente foram as variáveis analisadas neste projeto. Os resultados preliminares indicam que é viável usar esta tecnologia de remediação do solo no aumento da taxa de lixiviação de minerais de ouro e prata.

PALAVRAS-CHAVE: electrocinética; coluna de lixiviação; ouro; prata.

1. INTRODUCTION

Gold is seen as the noblest metal found in nature (Nicol et al , 1992) due to its low reactivity with oxygen, water and strong acids. The dissolution of this noble metal occurs in oxidizing solutions containing certain complexing agents, such as, cyanide, halide, thiosulfate, thiourea and thiocyanate (Marsden & House, 2006). Gold compounds and its species in solution are found almost exclusively in the oxidation states Au (I) and Au (III) (Marsden & House, 2006).

The main breakthrough in understanding the chemistry of cyanidation in gold was made by Kudryk and Kellogg in 1954. They could demonstrate the electrochemical nature of gold cyanidation (Menne, 1992). The gold dissolution reaction, known as Elsner equation (Menne, 1992), can be written as:



Gold and silver dissolution process in cyanide solutions involves heterogeneous reactions in the solid - liquid interface, as shown in Figure 1. Therefore, the following stages can be considered as fundamental sequential stages in the leaching process of these noble metals (Marsden & House, 2006):

1. Oxygen Absorption in the solution;
2. Transport of cyanide and dissolved oxygen to the solid – liquid interface;
3. Adsorption of (CN^- and O_2) reactants on the solid surface;
4. Electrochemical reaction;
5. Desorption of gold - cyanide, silver - cyanide soluble complexes and other reaction products from the solid phase;
6. Transport of desorbed products into the solution.

The electrochemical reaction stage is rarely determining a gold extraction process and therefore the mass transport step is often the limiting step reaction (Marsden & House, 2006).

The application of electric current to accelerate and direct the movement of metallic ions has been used in the remediation of soils contaminated with heavy metals. (Acar & Alshwabkeh, 1993).

When an electric potential difference is applied to a moist mineral bed, the electric current is transported by the ions existing in the solution. The process of transporting ionic species in solution through a mineral porous bed, by applying an electric potential difference consists of the mass flow by diffusion, migration and electroosmotic convection. The contribution of each type of flow in the total mass flow is affected by factors such as the ore mineralogical composition and the conductivity of the solution; the electrochemical properties of the species present in the fluid and the porosity and tortuosity of the mineral bed (Acar & Alshwabkeh, 1993).

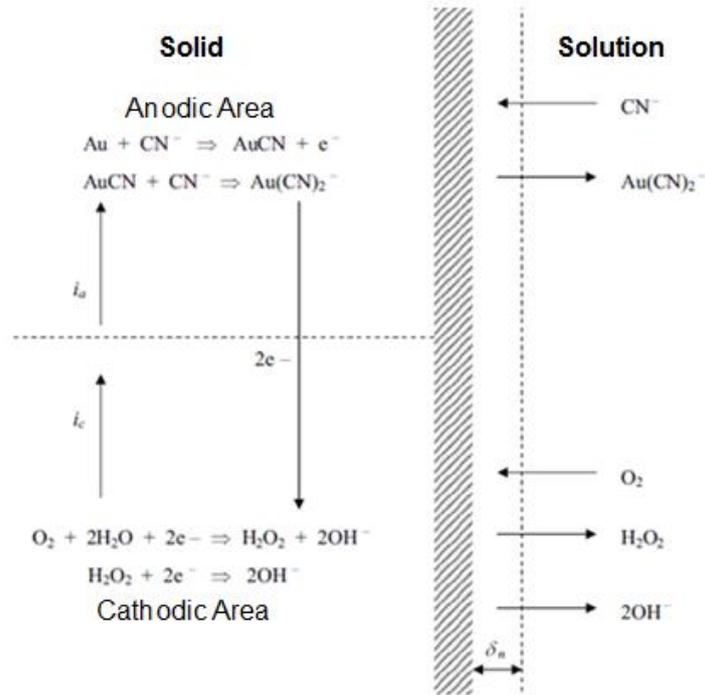


Figure 1. Schematic representation of a local corrosion cell in the surface of gold in contact with a cyanide solution containing oxygen, i_a = anodic current, i_c = cathodic current (Marsden & House, 2006).

Mass flow may occur due to ion migration, that is, the movement of ionic species contained in the interstitial fluid when applying an electric potential difference, and the degree of migration will depend on the mobility of the ionic species (Reddy & Cameselle, 2009). The migrational flux of a species j can be expressed by the following equation (Acar & Alshawabkeh, 1996):

$$J_j^m = -C_j(U_j^* + K_e) \frac{\partial E}{\partial x} \quad (2)$$

Where J_j^m is the migrational mass flow, C_j is the species concentration j , U_j^* corresponds to the effective ionic mobility, K_e is the coefficient of electroosmotic permeability, E is the electric potential difference, and x corresponds to the distance.

The ratio of the effective ionic mobility for a charged species under an electric gradient unit regarding the effective diffusion coefficient for the same species is about 40 times the charge of that species. Also, the transport of species by ionic migration will be at least 10 times higher than the transport of mass by electroosmosis, and can reach values up to 300 times at later stages (Acar & Alshawabkeh, 1993), thus migration is the largest transport process for ionic species (Acar & Alshawabkeh, 1993).

The purpose of this study is to evaluate the feasibility of using an electric potential difference in the leaching of mineral containing quantities of gold and silver, by taking advantage of electrokinetic principles applied for the remediation of contaminated soils with heavy metals.

2. EXPERIMENTAL

A series of tests of electrokinetic leaching with an auro-argentiferous mineral, in column leaching reactors specially designed for this purpose, were conducted, as shown in Figure 2. A specific distribution of particle size, set for filling the reactors, was established in order to avoid any plugging, and assess the percentage of recovery of gold and silver in each particle size at further stages. The distribution of particle sizes is shown in Table 1.

Table 1. Mineral granulometry.

Opening size (μm)	Mass retained (%)	Cumulative retained (%)
2800	350	24,1
2360	100	31
2000	700	79,3
600	150	89,7
300	100	96,6
177	30	98,6
pan	20	100

Once the reactors were loaded with the mineral, they were saturated with a solution of 0.04 M NaCN, since it is a cyanide concentration commonly used in gold metallurgy. Differences in electric potential were applied by DC power supplies BK Precision 1440B. Voltages used in the leaching stage (and determined in preliminary stages) were 0, 5, 30, and 60 volts; current was set at 4 Amp.

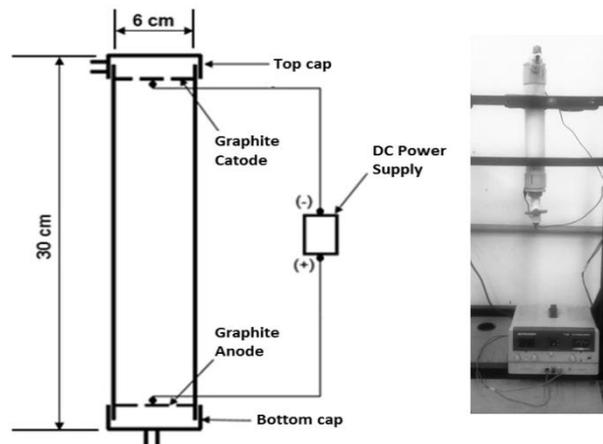


Figure 2. Column reactor manufactured for electro-leaching testing.

The electro-leaching stage starts once the power supplies are turned on. The electrode at the bottom of the reactor serves as an anode and the one at the top serves as a cathode. The electrodes are arranged in such a way that the complex of silver and gold ($\text{Au}(\text{CN})_2^-$ and $\text{Ag}(\text{CN})_2^-$) can migrate to the bottom of the reactor. Samples of the leach liquor from the bottom of the reactor were taken at time intervals of 2, 4 and, 24 hours. Further analysis were taken using atomic absorption spectrophotometry with a ThermoscientificCE 3000 series equipment. The anodes were analyzed by scanning electron microscopy with a Phenom Pro X equipment.

3. RESULTS AND DISCUSSION

Once the gold-silver complexes are formed, they will migrate following the direction of the current, that is, toward the graphite anode, where they will be adsorbed due to the applied electrical potential.

According to Equation 4, the higher the electric gradient is, the faster the species migrate towards the anode. By applying an electric potential difference to a column leach, the migration of silver and gold species will be encouraged. This will cause an increase in the leaching rate, as the transport of species is very often the limiting stage in the leaching reaction.

Figures 3 and 4 show that the concentration of gold and silver decreases as the electric potential increases, since the migration speed is higher as the potential increases and its concentration decreases.

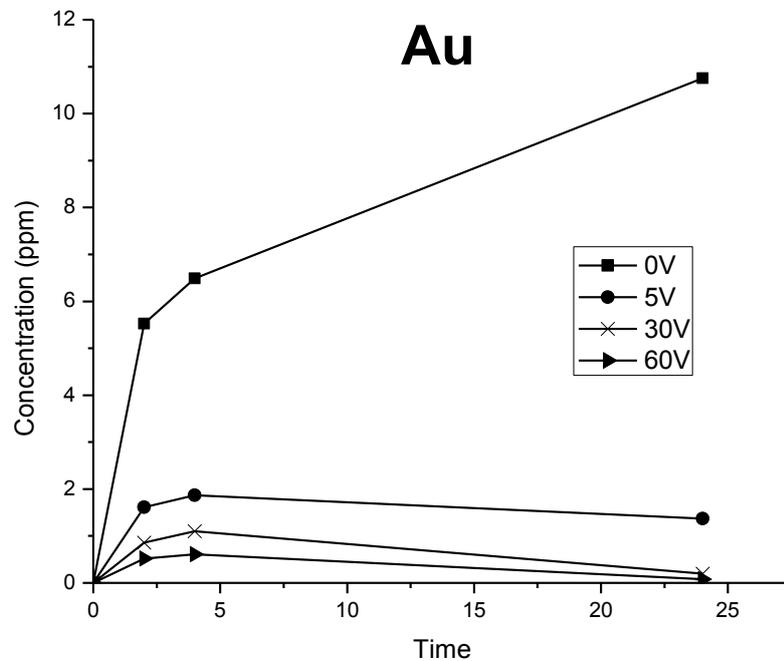


Figure 3. Gold concentration in the anodic fluid at different electric potentials.

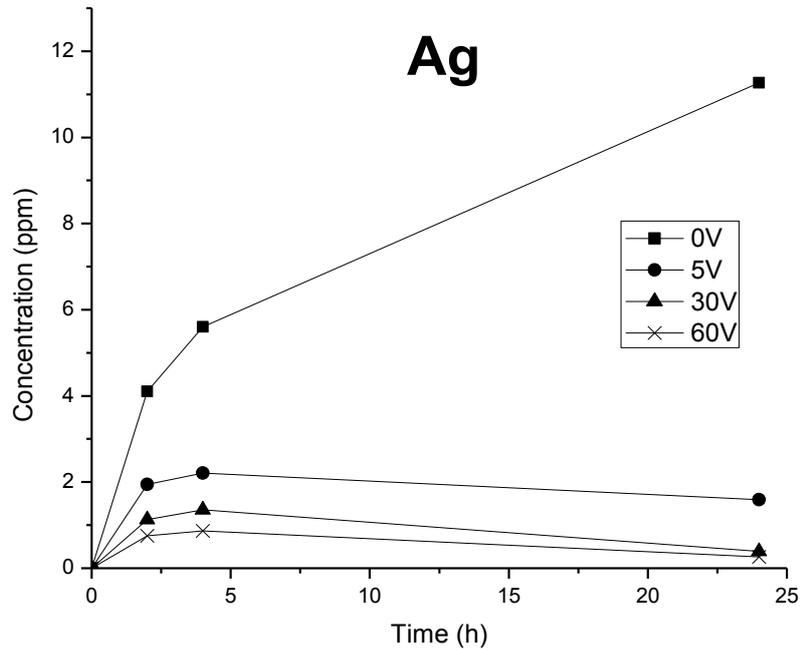


Figure 4. Silver concentration in the anodic fluid at different electric potentials.

To support the results shown in Figures 3 and 4, analyses of graphite anodes were conducted by scanning electron microscopy. In such analyses it is possible to observe the presence of gold and silver (see Figure 5). This would indicate the reduction of $\text{Au}(\text{CN})_2^-$ and $\text{Ag}(\text{CN})_2^-$ complexes (as well as other complex presented) which occur in the anodic liquor and in the subsequent deposition of gold and silver on the electrode surface.

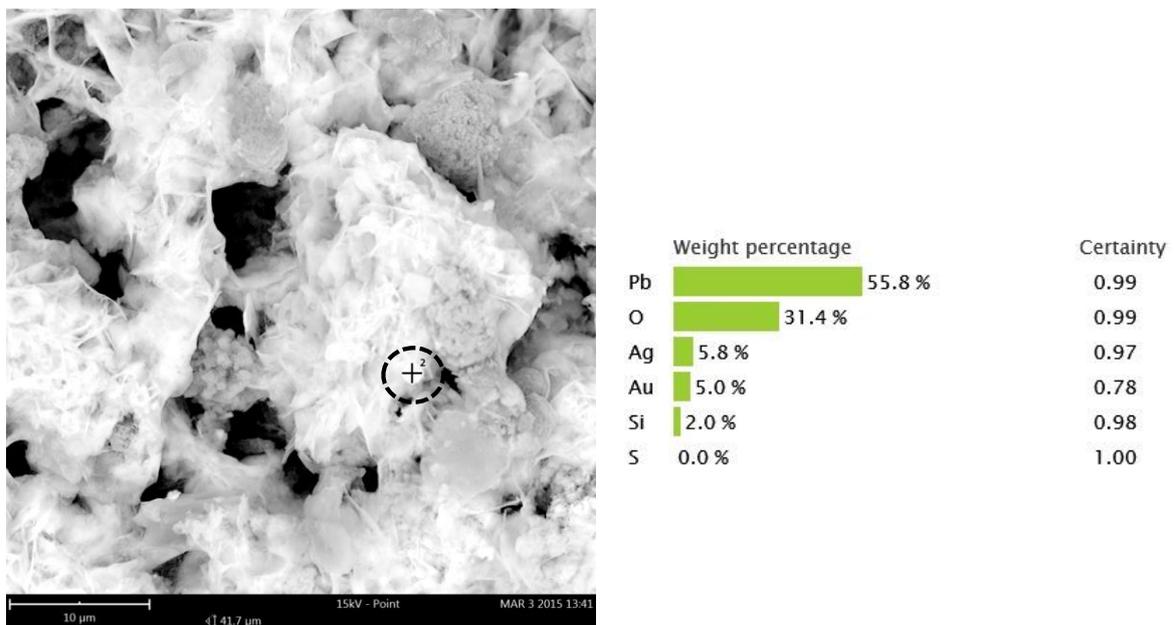


Figure 5. SEM Image with EDS for the graphite anode.

4. CONCLUSIONS

- Once the complexes of gold and silver are formed because of the cyanide, these will migrate towards the anode due to the phenomenon of ionic migration promoting, in such way, the transport of species;
- By promoting the transport of gold and silver species by means of a difference in the electric potential, the leaching speed could be increased since the stage of transport of species is the one that limits the leaching reaction;
- The gold and silver ionic species tend to disappear from the solution, as they are reduced by the anode.

5. ACKNOWLEDGMENTS

The authors express their gratitude to the Universidad Nacional de Colombia (National University of Colombia) for its financial support in the project “electrokinetic applied to leaching of auro-argentiferous minerals”, registered under the Code 19848, as well as to CECOLTEC S.A.S Company, and to the engineers Gali Quitian and Carlos Salazar for their support and help in this project.

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