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# Leaching kinetics in cyanide media of Ag contained in the industrial mining-metallurgical wastes in the state of Hidalgo, Mexico

Juan Hernandez *, Francisco Patino, Isauro Rivera, Iván Alejandro Reyes, Misrael Uriel Flores, Julio Cesar Juarez, Martín Reyes

*Research Centre in Materials and Metallurgy, Autonomous University of Hidalgo, Pachuca 42184, Mexico*

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ABSTRACT

The leaching kinetics in cyanide media of the silver contained in the Dos Carlos waste tailings at the City of Pachuca de Soto, Hidalgo State, Mexico were carried out. The used material contained the following chemical composition: $56 \times 10^{-6}$ of Ag, $0.6 \times 10^{-6}$ of Au and 70.43% (by weight) of $SiO_2$; 7.032% (by weight) of $Al_2O_3$; 2.69% (by weight) of Fe; 0.46% (by weight) of Mn; 3.98% (by weight) of $K_2O$; 3.34% (by weight) of CaO; 2.50% (by weight) of $Na_2O$; 0.04% (by weight) of Zn; 0.026% (by weight) of Pb. The mineralogical phases present were the following: Silica, albite, argentite, berlinite, orthoclase, potassium jarosite, and natrojarosite. In the leaching kinetics in cyanide media, and under the studied conditions, the effect of the $CN^-$ concentration on the reaction rate has no effect on the whole process of alkaline cyanidation, of which the reaction order is $n \approx 0$. Temperature has an effect on the cyanidation rate of the reaction, with an activation energy of 47.9 KJ/mol. At the same time, when the particle size decreases there is an increase in the reaction rate, which is inversely proportional to the particle diameter; when increasing the NaOH concentration there is an increase in the reaction rate $K_{exp}$, with a reaction order ($n$) of 0.215 under the studied ranges.



## 1. Introduction

In the State of Hidalgo, the processing of ores containing silver and gold has included technologies ranging from the patio process (grinding-amalgamation) and the Pachuca tanks, to the circuits with current technologies like grinding, flotation and cyanidation. All of these have generated a considerable volume of waste tailings of 112 million tons that take up 2000 hectares, resulting in four deposits of this material, which is very important in the State of Hidalgo for its Ag and Au contents of $30 \times 10^{-6}$–$130 \times 10^{-6}$ Ag and $0.3 \times 10^{-6}$–$1.0 \times 10^{-6}$ Au [1–5]. This is due to the metal mining activity that has been carried out in the region for more than 454 years [4]. The oldest wastes are evidently found in the deposits' bottom, and are the ones that present higher Ag and Au contents. Because of the ton, the metallic laws and these metals' prices on the market, especially silver, these deposits are very attractive from an economic point of view. Among the problems found with these tailings, we can cite the existence of pyritic and quartziferous ores, where the gold and silver values are encapsulated in the quartz particles, of which the predominant size in percentage terms is −75 μm (60%–65%), making this kind of metals' extraction difficult [6]. Besides, the presence of some cyanide-consuming elements and species (cyanicides), such as pyritic ores, in many cases helped us from achieving a proper extraction of the metallic values of Ag and Au. It has also been observed that the silver contained in jarosite-type compounds poses a metallurgical problem, causing erratic recoveries of this precious metal [7,8]. For these reasons, it is necessary to carry out an alkaline cyanidation study of the waste tailings in order to determine the optimal conditions and the highest recoveries of this metal.

## 2. Experimental procedure

The Dos Carlos waste pile, located in the urban zone of the City of Pachuca, Hidalgo, Mexico was chosen for this study. Four representative samples of 50 kg were taken, and a thorough characterization was performed by X-ray fluorescence (FRX) using a vaccum-operated SIEMENS spectrometer. The sample was irradiated with an Rh anticathode using the following crystals: LiF200, Ge111 and T1AP; the equipment calibration was performed with different mineral oxides of known composition. The X-ray diffraction (XRD) was carried out by using a Phillips X-pert Gateway 2000 XRD. Atomic Absorption Spectrometry (AAS) was used

* Corresponding author. Tel.: +52 017717172000.
*E-mail address:* herjuan@uaeh.edu.mx (J. Hernandez).

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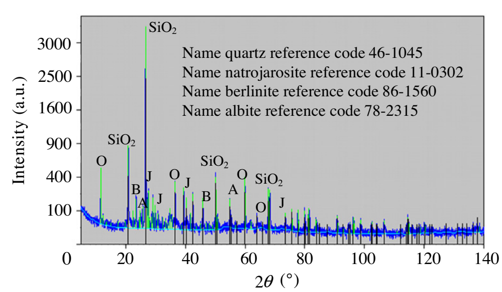
**Table 1**
Waste pile's chemical analysis by XRF.

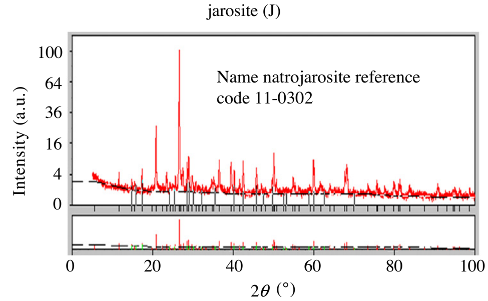
| Element | Weight percent (%) | Element | Weight percent (%) | Content (g/ton) |
|---|---|---|---|---|
| $SiO_2$ | 70.43 | $P_2O_5$ | 0.120 | |
| $TiO_2$ | 0.53 | $K_2O$ | 0.080 | |
| $Al_2O_3$ | 7.32 | $SO_3$ | 0.940 | |
| $Fe_2O_3$ | 2.80 | ZnO | 0.045 | |
| MnO | 0.73 | PbO | 0.031 | |
| MgO | 0.54 | Ag | | 55 |
| CaO | 0.69 | Au | | 0.58 |
| $Na_2O$ | 0.08 | | | |

to determine the Zn, Cu, Pb, Fe and Si concentration in a Perkin Elmer 2380 spectrometer. Inductively Coupled Plasma (ICP) was used for assessing the S, Ag and Au concentration-the equipment was a Perkin Elmer Optima 3000 XL. SEM was performed for the morphology study of the tailings' particles and Energy dispersive X-ray spectroscopy (EDS) was carried out to determine the nature of the studied material. An EDS-equipped Jeol JSM 5900LV SEM was used for this matter.

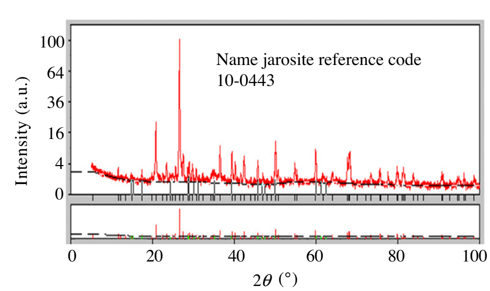
The mineral used for the leaching kinetic study was previously ground. We found that the optimal grinding time is 8 min, because at this grinding time 52% of the Ag is found in the predominant sizes of $-88+74$ μm. The samples for the study were obtained from this material [1]. The leaching experiment was performed in a PYREX flat-bottom glass reactor, 1000 mL capacity. It was mounted on a heating plaque and magnetic stirring was applied with supernova equipment, tolerance limit of ±0.2 °C and stirring rate of 1200 r/min. The reactor had a cover with a refrigerant for avoiding liquid loss by evaporation. The solids were kept in suspension during the whole experiment by magnetic stirring; pH was measured with a Cornig pH/ion analyzer 455 pH-meter, equipped with an ATC 0627 temperature meter and a pH electrode suitable for operating under extreme acidity and alkalinity conditions (0–14 pH range). An OHAUS Analytical Plus AP210S digital analytical scale with precision of 0.0001 mg was used to determine each sample's weight. The leaching kinetics in cyanide media were carried out under the following experimental conditions: $CN^-$ between $5\times10^{-2}$ and $5.1\times10^{-3}$ mol/dm$^3$; the temperature effect was studied in a range going from 288 K to 338 K; the mineral




(a) X-ray diffractogram of the tailings, of which the main mineral species are quartz ($SiO_2$), orthoclase (O), albite (A), berlinite (B) and jarosite (J)




(b) Diffractogram showing the presence of sodium jarosite ($NaFe_3(SO_4)_2(OH)_6$)




(c) Diffractogram showing the presence of potassium jarosite $KFe_3(SO_4)_2(OH)_6$ in the tailings

**Fig. 1.** Presence of quartz, argentite, albite, berlinite, orthoclase, potassium jarosite and natrojarosite.