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Parametric Study of the Extraction of Cadmium from an Algerian Phosphate Ore (Djbel Onk)

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ABSTRACT

The main objective of this work is to extract the Cadmium contained in the phosphate ore of Djebel Onk by chemical means (acid leaching). Firstly, we tested a certain number of extracting agents in order to choose the most effective. The results obtained show that among the different agents used, hydrochloric acid gives the highest extraction rate. This result is even more interesting knowing that this extractant is used in the manufacture of phosphoric acid. To this end, the study is oriented towards two objectives. On the one hand, the recovery of cadmium and on the other hand the production of phosphoric acid.

Keywords: cadmium, phosphate, extraction, leaching, Chloridric acid, Phosphoric acid, modeling, optimization, Behnken box experiment design.

1 Introduction

Cadmium, although a toxic element [1], has significant utility in various industries. Its inclusion in rechargeable batteries, notably nickel-cadmium batteries, offers high energy density and long cycle life, making them valuable for electronic devices and electric vehicles [2]. And phosphate ore, a major source of phosphorus used in the manufacture of fertilizers and other chemicals, can contain varying concentrations of cadmium [3]. Algeria is a country rich in phosphate and it also has a considerable reserve. One of the largest reserves is the Djbel Onk mine; in the Wilaya of Tebessa; for its high P_2O_5 content of around 30%, with a Cadmium content estimated at 36ppm. A quantity that remains usable can be recovered during the processing of phosphate ore for its various uses [4;5].

2 Experimental

To carry out this work, we first carried out the characterization of the phosphate ore using different techniques, namely : DRX, FTIR, ED/XRF and ATG/ATD. And we found that: phosphate ore is rich in P_2O_5 (29%); fluorapatite is the majority phase with a content of 68.7% ; its Cadmium content is around 21ppm; the presence of C-O and P-O groups characterizes a carbonate phosphate ore. Several parameters influence the cadmium extraction procedure, and we found it useful to select and study a certain number of them in order to be able to come out with the best possible combinations giving optimal extraction yield, such as: the choice of the extraction agent; reaction time; the grain size of the ore; the Solid/Liquid molar ratio; the concentration of the chosen dissolving agent. The influence of Cadmium extraction parameters was studied by adopting progressive steps for the determination of optimal operating parameters. These steps include firstly changing- the nature of the extraction agent (lixiviant) in order to select the most suitable among [6;7]: tartaric acid $(CHOH.COOH)_2$; hydrochloric acid HCl; citric acid $C_6H_8O_7$; ammonium acetate CH_3COONH_4; disodium ethylene diaminetetra acetic Na_2EDTA. During this stage, we also evaluated the influence of the presence of organic matter on the cadmium extraction process by the different selected agents, using a previously oxidized ore. Subsequently, a kinetic study was carried out to determine the necessary and sufficient time to reach equilibrium or the maximum extraction rate. And finally we studied the distribution of the level of cadmium and P_2O_5 in the different particle size classes of the ore in order to work on the richest fractions. During all stages, analytical monitoring was carried out by measuring the level of cadmium by atomic absorption spectrometry, and of P_2O_5 by UV-visible. Following

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the results of characterizations, preliminary tests and bibliographic research[6 ;7], we were able to set certain parameters and determine the areas of study of others for the rest of the work. Subsequently, the parametric study of the extraction was started, and planning of experiments according to the Behnken box model was applied. The effect of the chosen parameters on the leaching efficiency of Cd and P_2O_5 was studied in the defined areas [8; 9].

3 Results and Discussions

We initially noticed that the presence of organic matter causes a sort of extraction barrier for the two substances Cadmium and Phosphorus. We also note that chloridric acid 'HCl' gives the best Cadmium extraction yield under the operating conditions adopted, not only that, but also it gives a good Phosphate extraction yield. In light of these results, we worked for the rest of the project with a previously oxidized Phosphate ore, and with Chloridric acid as an extracting agent. The kinetic study, at room temperature, shows that the extraction yield increases with time, and that equilibrium is reached after 2 hours 15 minutes.
The particle size ranges to study are : 0<Ø<100 µm ; 100<Ø<200 µm ; 200<Ø<300 µm ;
The field of study of molar concentration is : [0.1-2mole/L] ;
The field of study of the Solid/Liquid report is : [0.1-0.4] ;
In light of these results, the factorial design is established. where 17 tests were carried out; to model the process in order to develop an objective function expressing the Cadmium extraction yield as a function of the parameters studied. The results were processed using JMP pro 14 software.The results of the modeling and mathematical optimization allowed us to achieve a Cd extraction yield of 74.39% for optimal conditions : (ϕ = 128 μm, $R_{S/L}$ = 30 g.L-1, [HCl] = 1,81 mol/l). A cadmium extraction test under optimal conditions was carried out, the analysis by atomic absorption spectrometry and UV-visible gave a Cadmium extraction yield of 76.28% and a P_2O_5 dissolution yield of 73.62%.

4 Conclusion

This study allowed us to implement an experimental protocol aimed at a dual objective, on the one hand, the extraction of cadmium and on the other hand, the production of phosphoric acid from an Algerian phosphate ore (Djebel Onk, Tebessa), by Chloridric route. Factorial planning of experiments has proven to be very useful and effective for the study of Cadmium extraction from phosphate ore. This method allowed us to know the effects of the factors considered; that of the acid concentration turned out to be very significant. As well as the value of the Cd extraction yield is very close to the optimal yield of our model which is 74.38%, and only confirms its reliability and efficiency.

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