Uranium Recovery from Liquid Waste Composed of Uranyl Nitrate Solution

CAMPELO, E. L. C[1,2]., FONSECA, F. V[2]., MEDRONHO, R. A[2]., PEREIRA, W[1,2]., SANTOS, R. D[1]
[1]Brazilian Nuclear Industries, [2]Federal University of Rio de Janeiro
E-mail: emanuelecampelo@inb.gov.br

ABSTRACT

- Nuclear energy to generate electricity is an important and low carbon emission source.
- This work aims to reduce nuclear waste and return uranium that was waste to produce UO_2 pellets using a Central Composite Rotational Design (CCRD), considering uranium recovery, pH, reaction time and hydrogen peroxide mass as study factors to optimize the uranium recovery .
- The initial concentration of uranium in solution was 13.9 $g{\cdot}L^{-1}$. Through experimental planning by Central Composite Rotation Design (CCRD), it was possible to optimize the treatment of this solution.
- After treatment with hydrogen peroxide with a concentration of 200 $g{\cdot}L^{-1}$ with pH adjustment of the solution equal to 1.75, it was possible to recover 99.7 % of the uranium present in the initial solution.

BACKGROUND / INTRODUCTION

- During the operation of a nuclear facility, instruments and equipment may develop non-fixed contamination, which is easily transferred to other surfaces, or fixed contamination, which is not.
- The solution used in this study was nitric acid (HNO3 15 %) as a chemical method to remove uranium from surfaces and equipment.
- Alkaline precipitation methods, with calcium hydroxide (Ca(OH)2) or ammonium hydroxide (NH4OH) are highly efficient to remove the uranium, but they lead to a product that is not suitable to use in INB's manufacturing process. An adequate route to treat this solution and recover the uranium is through a uranium peroxide precipitation seen in Eq. 1.

$$UO_2^{2+} + H_2O \longrightarrow UO_2(O_2).xH2O + 2H^+ \qquad Eq.1$$

- The advantage of designing experiments is the reduction in the number of tests and the need to repet them, as well as the simultaneous analysis of variables.

METHODS

Instrumentation

- A PerkinElmer Optima 2100 DV ICP-OES was used for quantitative measurements and Statistica® version 10.0.228.2 was used for the experiment design.

Optimization strategy

- Based on the best uranium recovery values from the findings in the preliminary tests, it was possible to establish the main variables to be studied and their levels to find the optimum point for more uranium removal from the solution and lower costs.
- The study was based on a CCRD with pH adjusted, reaction time, and hydrogen peroxide added mass as independent variables. The residual uranium concentration was used as dependent variable.

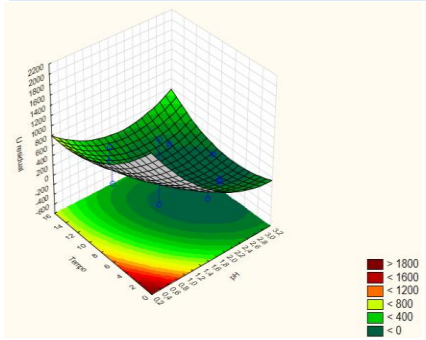

Figure 1. Response surface.

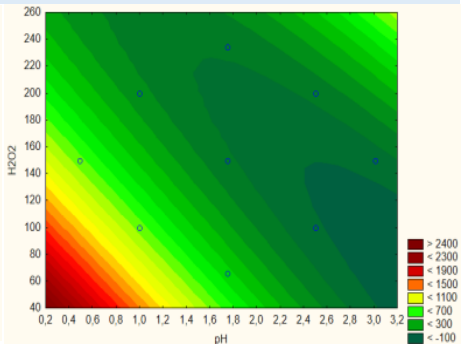

Figure 2. Contour curve for residual U.

OUTCOME / RESULTS

ID: IAEA-CN294-012

- pH was considered in the proposed model as the main effect, and the interaction between the variables pH and hydrogen peroxide concentration comes next.
- Uranium precipitation increases when pH increases, and uranium recovery is changed over time (Figure 1).
- With the results of the design of the experiment was created the response surface, relating two independent variables - pH and concentration of hydrogen peroxide added - with the result of the dependent variable - uranium recovery. It is possible to observe that greater uranium precipitation is obtained by increasing the concentration of hydrogen peroxide and with a pH closer to 3 (Figure 2). An important point to be considered is the precipitate formed, since above pH 3 there is the formation of other uranium compounds.
- The design of experiments brings information relating the variables, being possible to obtain an optimal uranium recovery, adjusting the production and variables as needed. It was possible to optimize this treatment, to generate minimum waste, the lowest possible use of reagents, gains in operational time, and mainly, to define the best treatment conditions for the uranyl nitrate solution, obtaining the highest precipitation and returning this uranium precipitate to the production of UO_2 powders and pellets.

CONCLUSION

Starting from an initial uranium concentration of 13.9 $g{\cdot}L^{-1}$, only 36.10^{-3} $g{\cdot}L^{-1}$ of 5 % enriched uranium remained in solution and the uranyl peroxide precipitate can be returned for UO_2 production recovering about US$ 4.000,00. The remaining solution was treated with CaO and the final uranium concentration was less than 5.10^{-3} $g.L^{-1}$.

Considering the 3 m^3 of initial solution the volume that would be generated only by treating with CaO is 180 kg of CaO containing U; Waste volume that will be generated only by treating with hydrogen peroxide and only polishing with CaO is 30 kg of CaO containing U and the possibility of recovering 62.8 kg of U to return to the process.

ACNOWLEDGEMENTS

Brazilian Nuclear Indutries
Federal University of Rio de Janeiro - Chemistry School