REDUCTION OF PROCESS WATER CONSUMPTION IN URANIUM ACID DYNAMIC LEACHING

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ABSTRACT

In 2006 the Argentinean government announced its plans to reactivate the nuclear program. As a result of this decision, the Atomic Energy National Commission (CNEA) of Argentina restarts their researches in the uranium mining process of Argentinean ores bodies. The first step was the study of the leaching process, mainly dynamic leaching. In the current paper parameters of acid dynamic leaching for two different solids content (53% and 66% w/w) in ground ore pulp have been studied, in batch scale, to evaluate the process behavior together with the reduction of process water consumption. Acid concentration, oxidant concentration and reaction temperature were the studied parameters. Sandstone type uranium-molybdenum ores were used for those tests. Changes in geometrical and dynamic condition were necessary for tests with 66% solids content in ground ore pulp. Finally, a comparison of best acid dynamic leaching condition for each test (53% and 66% w/w) was made. As a result, over 90% of uranium was extracted reducing around 50% of the consumed process water (380 liters of water per tones of ores).

KEYWORDS: dynamic leaching; mining process; uranium; process water; solids content.

1. INTRODUCTION

Argentinean government announced in 2006 its plans to reactivate the nuclear activity. This nuclear plan mainly focuses on nuclear energy production to satisfy energy requirements and diversify its energy mix power generation. Lined up to this, the construction of the third nuclear power plant was restarted. As a result of this decision, the Atomic Energy National Commission (CNEA) of Argentina restarts its researches in the uranium mining process of Argentinean ores bodies with the objective to satisfy future local demand of uranium concentrate (yellow cake) for Argentinean nuclear fuel.
As it is well known, for the development of a mining process the first step is the study of the leaching process. In this step, the mineral ore characteristics are the key to select the best leaching conditions. Sandstone type uranium-molybdenum ores were used for these tests. Acid dynamic leaching was select as a leaching process after an evaluation of the mineral ore characteristics and the laboratory-scale tests results.
Nowadays, in a complex mining public context, a sustainable mining process development is a requirement. Taking care of that issue the reduction of process water consumption is necessary and is the motivation of this work.
Acid dynamic leaching for two different solids content (53% and 66% w/w) in ground ore pulp have been studied, in batch laboratory-scale, to evaluate the process behavior with reduction of process water consumption.

2. METHODOLOGY

2.1. Acid dynamic leaching

The leaching tests were done at laboratory-scale in batch process. Mechanical agitation during the test was used. An improved acid dynamic leaching process, development in our laboratories, was used. This method suggested the use of strong acid (H_2SO_4) in excess that is added in one step to the ground ore pulp at the beginning of the test, achieving with this a greater initial driving force when compared to that of the conventional method and in this way reducing the test time. The oxidant agent (MnO_2) is also added at the same time.

About 100g of ground ore is mixed with the necessary amount of process water to get the required pulp (53% or 66% w/w) in a glass beaker. The process water used for the tests was fresh water without any treatment. Before the mixing started certain amount of strong acid and oxidant agent is added depending on the test specification. The test time was set up in six hours (6hs) and test temperature was set up, depending on the test specification, and mantained with a water bath.

2.2. Solid-liquid separation, washing and analysis

The pulps resulting from each test were filtrated with vacuum filtration system. After that these obtained cakes were washed four times with certain amount of washing solution (sulfuric acid solution at pH= 1). The leached solution was analyzed for uranium and molybdenum by inductively coupled plasma optical emission spectrometry (ICP-OES)

3. RESULTS AND DISCUSSIONS

Acid concentration, oxidant concentration and temperature were the parameters under study during the acid dynamic leaching tests. These parameters were studied under two different solids content in pulp (53% and 66% w/w) looking for the reduction of process water consumption without losing excessive extraction efficiency. The extraction efficiency of uranium (U) and molybdenum (Mo) were calculated for each condition.

3.1. Sample ore under study

The mineral used is a sandstone type uranium-molybdenum deposit, with averaging 0,2% uranium and 0,1% molybdenum with variable U/Mo ratio. Uranium is presented as uranium-organic material association, uraninite and conffinite minerals.
The ore was grounded with a jaw crusher and then milled using a disc mill, reaching a particle size average of 0,210 mm.

3.2. Acid dynamic leaching with 53% solids content

In this group of tests the three parameters were studied independently, changing only one parameter for each test while keeping fixed the others, the classical one-factor-at-a-time strategy (BUYDENS, 1997). The experimental conditions and the results of the performed tests are given in Table I.

Table I. Acid dynamic leaching tests with 53% solids content.

Test Nº	H_2SO_4 Kg/t	MnO_2 Kg/t	Temp. ºC	Uranium Extraction %	Molybdenun Extraction %
1	200	20	60	**83,8**	**82,1**
2	182	20	60	**93,4**	**84,9**
3	175	20	60	**94,9**	**88,3**
4	175	20	40	**91,4**	**82,2**
5	175	18	40	**76,8**	**67,2**

* Kg/t = kilogram per ton of ore

3.2.1. Acid concentration

The strong acid (H_2SO_4) concentration for each test was varied in a range of 175 to 200 Kg/t (kilogram per ton of ore) according to the requirements for the method. The oxidant agent concentration and the temperature were fixed (test nº 1, 2 and 3 of Table I).

As it is shown in Figure 1, the uranium and molybdenum extraction improved when the acid concentration was reduced. This effect is probably a consequence of the interactions between the oxidant agent and the high level of strong acid excess (BURLING, 2010).

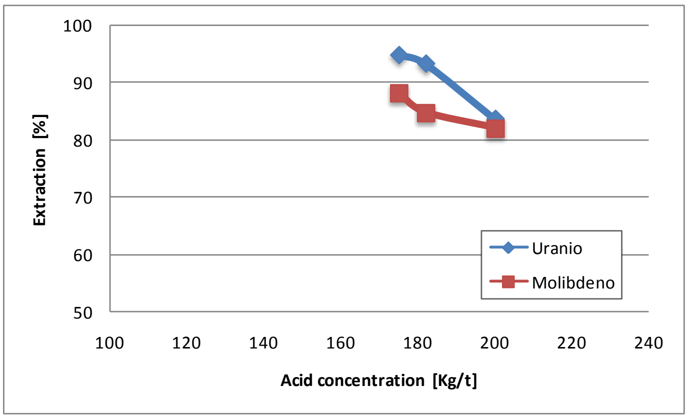

Figure 1. Acid concentration tests (53% w/w), 20 Kg/t MnO_2, 60ºC.

3.2.2. Oxidant concentration

Two different oxidant (MnO_2) concentrations were tested: 18 and 20 Kg/t (kilogram per ton of ore). These values were selected according to the optimum ORP range to oxidize the uranium (IV) present (MERRIT, 1971). The strong acid concentration and the temperature were fixed (test nº 4 and 5 of Table I) as well.

The oxidant concentration affect significantly the extraction efficiency, a little change on it cause a considerably drop on uranium and molybdenum extraction. (See Figure 2)

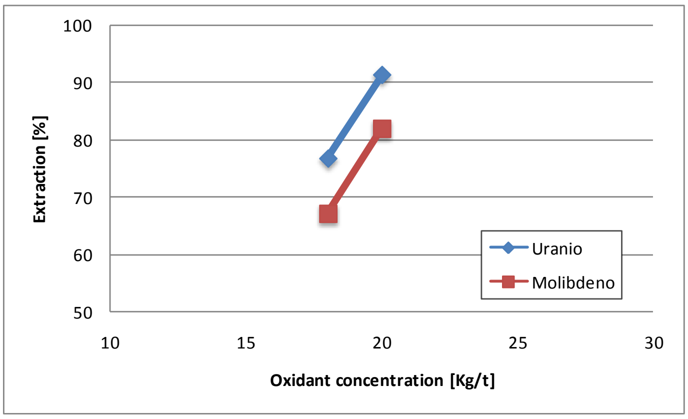

Figure 2. Oxidant concentration tests (53% w/w), 175 Kg/t H_2SO_4; 40ºC.

3.2.3. Leaching temperature

The heating requirements for the leaching process always increase the plant cost: better materials, auxiliary steam lines, evaporation leaks, etc. Then while searching to minimize heating requirements, two different process temperatures were tested: 40 and 60ºC. The strong acid and oxidant agent concentrations were fixed (test nº 3 and 4 of Table I).

The variation on the process temperature does not produce a significant effect on uranium and molybdenum extraction (See Figure 3). It could suppose that the strong acid excess may minimize the effect of the process temperature (MERRIT, 1971).

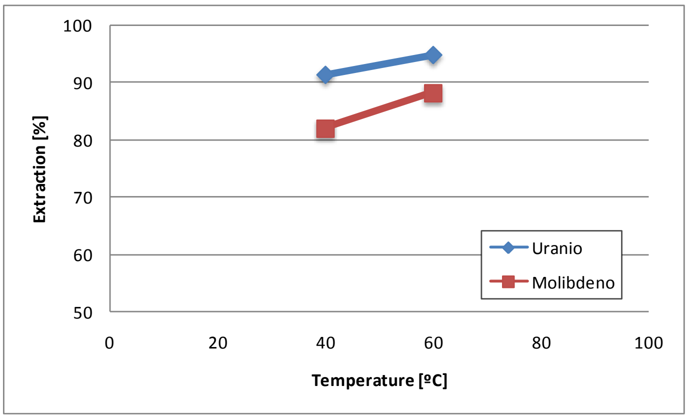

Figure 3. Process temperature tests (53% w/w).

3.3. Acid dynamic leaching with 66% solids contents

The tests with 66% w/w solids content in pulp were carried out by means of a factorial study (full two-level factorial design) (BUYDENS, 1997). Appling this kind of experimental study, the effect of all of the combinations of different individual factors (parameters) could be jointly assessed on the uranium and molybdenum extraction solutions. The factorial study was designed with three factors-two levels (see Table II) so it was needed eight (2^3=8) tests to cover all different situations. The experimental conditions and the results of the performed tests are given in Table III. This factorial study was done without replicates for each test because the ore sample was limited.

Table II. Full two-level factorial designs.

Factor			Level	
			Low (-)	High (+)
A	Strong acid concentration	Kg/t	160	175
B	Oxidant agent concentration	Kg/t	5	20
C	Leaching temperature	ºC	40	60

* Kg/t = kilogram per ton of ore

Table III. Acid dynamic leaching tests with 66% solids content.

Test Nº	Test Name	Factor A	Factor B	Factor C	Uranium Extraction %	Molybdenun Extraction %
1	(1)	-	-	-	**87,5**	**78,2**
2	c	-	-	+	**92,2**	**79,2**
3	b	-	+	-	**93,1**	**83,1**
4	bc	-	+	+	**92,7**	**81,8**
5	a	+	-	-	**89,7**	**78,2**
6	ac	+	-	+	**89,9**	**78,7**
7	ab	+	+	-	**87,7**	**78,8**
8	abc	+	+	+	**87,7**	**82,2**

3.3.1. Results of the factorial study

The results of the tests were evaluated according to the technique of direct estimation of effects (BUYDENS, 1997) (Table IV) with the aim to determine which are the main factors that exert an influence on the results (uranium and molybdenum extraction).

Table IV. Factor and interaction effects.

		Factor			Interaction			
		A	B	C	AB	AC	BC	ABC
Effects	**Uranium**	-2,625	0,475	1,125	-2,575	-1,025	-1,325	1,225
	Molybdenum	-1,100	2,900	0,900	-0,850	1,050	0,150	1,300

In this case we did not replicate the experiments, because of that we cannot evaluate directly the interactions effects significance and we have to suppose that they are not significant (BUYDENS, 1997).

It is, also, good practice to determine the normal probability plots, to graphically evaluate if the effects would be considered significant or just a dispersion around zero according to a normal distribution. These normal probability plots of the effects for uranium and molybdenum extraction are shown in Figure 4 and 5 respectively.

Based on those plots, "A" the factor (strong acid concentration) is considered significant and affect negatively the uranium extraction (Figure 4). So it could be said, at least initially, that in order to improve the uranium extraction yield, minimizing the strong acid concentration (A) would be appropriate.

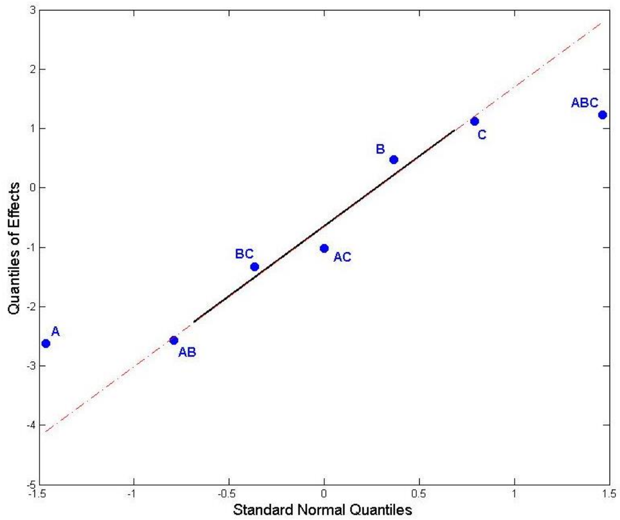

Figure 4. Normal probability plot of the effects for the uranium extraction performed tests.

For the case of molybdenum extraction, it seems that the most significant effect is the oxidant agent concentration (B), it favorably affects (Figure 5). So to improve molybdenum extraction the oxidant agent concentration should be maximized and strong acid concentration minimized.

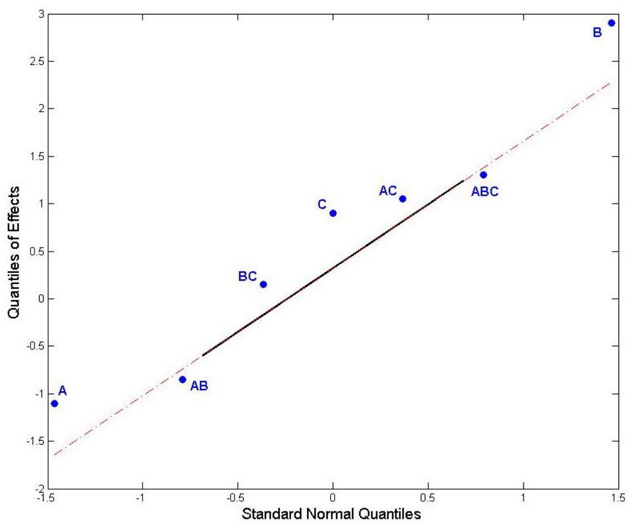

Figure 5. Normal probability plot of the effects for molybdenum extraction performed tests.

3.4. Process water consumption – Comparison

The process water consumption for both kinds of experiments (53% and 66% solids content) was different. The amount of ore and process water were fixed for each kind. The strong acid and the oxidant agent addition cause a small variation on pulps solids content for each experiment, they have been named them taking care of the average (see Table V).

Table V. Solids content in pulps.

Pulp	w/w	53				66			
		52,84	53,26	52,46	52,88	66,01	66,40	65,42	65,81
Ore	g	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
Process water	g	75,00	75,00	75,00	75,00	37,00	37,00	37,00	37,00
Acid	g	14,78[(1)]	14,78	16,16[(2)]	16,16	14,78	14,78	16,16	16,16
Oxidant	g	0,58[(3)]	2,32	0,58[(4)]	2,32	0,58	2,32	0,58	2,32
Total mass	g	190,36	192,10	191,74	193,48	152,36	154,10	153,74	155,48

(1) 160 Kg/t of H_2SO_4; (2) 175 Kg/t of H_2SO_4; (3) 5 Kg/t of MnO_2; (4) 20 Kg/t of MnO_2

In Table V it is shown the amount of process water that was necessary for each kind of experiment. It can be seen that for a 53% w/w pulp 75g (≈75 ml) had used of process water and for 66% w/w pulp only 37g (≈37 ml), representing a reduction of around 50% on the process water consumption. This figure has been written taking care the amount of ore, which represents a reduction of 380 liters of process water per ton of ore.

3.5. Agitation modifications for 66% solids content tests

A preliminary study was made to improve the agitation conditions for the tests with 66% w/w pulp. Geometrical and dynamic changes were necessary. Better conditions were reached by reducing the ratio between impeller and tank diameters, changing an axial flow impeller (propeller) for a radial flow impeller (turbine) and finally the power had to be increased.

4. CONCLUSIONS

The use of acid dynamic leaching with 66% solids content in ground ore pulp can reduce around 50% of the process water consumption (380 liters of process water per ton of ore) reaching over 90% for uranium extraction and 80% for molybdenum extraction yield respectively, similar recovery is obtained using 53% solids content in acid dynamic leaching but consuming more process water.

The three parameters under study have a similar behavior in both kinds of experiments. Strong acid concentration has a significant negative effect that must be minimized. Oxidant agent concentration is more important for molybdenum extraction than for uranium extraction when we work under 66% solids content experimental conditions and high leaching temperature do not produce a significant improve on the extraction.

Finally, improvements in geometrical and dynamic condition are necessary when high solids content in ground ore pulps is used.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

BURLING, S., MARLEY, M., RING, R., The effects of oxidation-reduction potential and ferric iron concentration on leaching of uranium ores. Proceeding of the 3rd International Conference on Uranium, 4thAnnual Hydrometallurgy Meeting, p 563-573. Ontario, Canada, 2010

BUYDENS, L.M.C., MASSART, D.L., VANDEGINSTE, B.G.M. Handbook of Chemometrics and Qualimetrics, v. 20, p 659-677, 1997

MERRIT, R.C., The extractive metallurgy of uranium. Colorado School of Mines Research Institute. U.S. Atomic Energy Commission. p 59-71, 1971