Available online at www.sciencedirect.com
ScienceDirect
Hydrometallurgy 85 (2007) 103–109
hydrometallurgy
www.elsevier.com/locate/hydromet

Resin-in-pulp method for uranium recovery from leached pulp of low grade uranium ore

Kazem Mirjalili *, Mahshid Roshani

Ore Processing Centre, Atomic Energy Organization of Iran (AEOI), Tehran, Iran

Received 11 May 2006; received in revised form 11 August 2006; accepted 16 August 2006
Available online 20 September 2006

Abstract

An improved process for the separation of uranium from the leached pulp of low grade uranium ore is reported using the resin-in-pulp method. For this study, four small pachucas were designed and calibrated. A series of tests were conducted batch-wise to determine the optimum conditions for uranium adsorption on a strong base anion exchange resin. The particle size of resin was 0.6–1.6 mm and the particle size of pulp was −0.1 mm. Flow rates of resin and pulp were adjusted on 10 ml/h and 1 ml/h, respectively. The redox potential of pulp was 500 mV and the pH of pulp was 1.8. A McCabe Thiele diagram was constructed for the process and the experimental results confirmed the theoretical predictions. It is concluded that four stage counter-current resin-in-pulp operation under optimum conditions is sufficient to recover about 99% of the uranium from the leached ore.

Keywords: Resin-in-pulp; Ion exchange; Uranium recovery; Pachuca column

1. Introduction

It is a common practice to leach uranium ores with sulfuric acid and to remove the uranium by passing the leach liquor through columns containing suitable ion exchange resins, which take out a complex uranium anion. When the resin has taken out as much as it can, an eluting liquid is then passed through, removing the uranium values and regenerating the ion exchange resin, which is then used to treat further amounts of leach liquor (Ford, 1984). This process, which has been used on a commercial scale, has certain drawbacks. The uranium ores are usually quite low grade, and the leach liquor has to be separated from a very large amount of ore solids. As a result there is a large filtration problem which adds markedly to the cost. The resin-packed columns also represent a relatively expensive construction cost which further increases plant fixed charges (Tatarnikov and Abramov, 1993; Anon, 1993). It has been proposed to eliminate the filtration step by exposing the leached ore pulp to resin in the form of moderately coarse beads, and then separating the uranium loaded beads from the ore solids in the pulp. This process is often referred to as the resin-in-pulp process (Laskorin et al., 1977; Arnold, 1981) and has been used in U.S.A, Russia, France, South Africa, China, Canada, and some other countries for separating the uranium from leached pulp (Laskorin et al., 1977; Skorovarov, 1975; Anon, 1993).

* Corresponding author. Tel.: +98 21 66505638.
E-mail addresses: kmirjalili@yahoo.com (K. Mirjalili), mahshidroshani@yahoo.com (M. Roshani).

0304-386X/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.hydromet.2006.08.006

2. Characteristics of ore

The major uranium mineral of this ore is uraninite. In most cases some uraninite minerals occur in relics of magnetite, where they have been excellently preserved. Much more seldom, uranium oxide is observed in serpentine and chlorite. A small portion of uranium is connected with urano-thorianite. In the re-deposited ores, uranium is generally concentrated in weeksite and to a lesser degree in boltowoodite and uranophane. The major gangue mineral is serpentine. In strongly weathered samples, serpentine is replaced by magnesia silicates of saponite–sepiolite type. At the sites of weakly altered serpentine, some chlorite and biotite remain.

Uranium and gangue minerals of the ore are given in Table 1 and results of chemical analysis are given in Table 2.

3. Description

3.1. Leaching process

To prepare leached pulp for resin-in-pulp process the optimum leaching conditions were as follows:

- Particle size: −0.1 mm
- H_2SO_4 consumption: 250 kg/t of ore
- MnO_2 as oxidation reagent: 5 kg/t of ore
- Temperature: 70 °C

Table 1
Uranium and gangue minerals of ore

Mineral type	Mineral name	Chemical formula
Uranium mineral	Uraninite	$(U^{4+}_{1-x},U^{6+}_{x})O_{2+x}$
	Weeksite	$K_2(UO_2)_2(Si_2O_5)_3.4H_2O$
	Boltowoodite	$K_2(UO_2)_2(SiO_3)_2(OH)_2.5H_2O$
	Uranophane	$Ca(UO_2)_2(Si_2O_7).6H_2O$
	Uranothorianite	Th_2UO_4
Gangue mineral	Magnetite	$(Fe,Mg)Fe_2O_4$
	Serpentine	$(Mg,Fe)_3Si_2O_5(OH)_4$
	Talc	$Mg_3Si_4O_{10}(OH)_2$
	Chlorite	$(Mg,Fe^{2+},Fe^{3+})_6AlSi_3O_{10}(OH)_8$
	Hematite	Fe_2O_3
	Biotite	$K(Mg,Fe^{2+})_3(Al,Fe^{3+})Si_3O_{10}(OH)_2$
	Apatite	$Ca_5(PO_4,CO_3)_3(Fe,OH,Cl)$
	Opal	$SiO_2.xH_2O$
	Gypsum	$CaSO_4.xH_2O$
	Plagioclase	$(Na,Ca)Al(Si,Al)Si_2O_8$
	Epidote	$Ca_2(Al,Fe^{3+})_3(SiO_4)_3(OH)$
	Feldspar	$(K,Na,Ca,Rb,Ba,Sr,Fe)Al(Al,Si)_3O_8$
	Chalcopyrite	$CuFeS_2$
	Breunnerite	$(Mg,Fe,Mn)CO_3$

Table 2
Results of chemical analysis of ore

Compound	ppm	Compound	ppm	Compound	Percent
U	348	Co	100	V_2O_5	0.34
Th	35	Pb	10	SiO_2	25.47
Mo	70	Sc	10	TiO_2	0.44
Ni	220	Sn	<10	Al_2O_3	2.16
As	130	Bi	<30	Fe_2O_3	32.14
Zr	<5	Cd	<100	FeO	3.97
Se	<10	Hg	–	MnO	<0.01
Y	<50	Ba	<30	CaO	1.22
Nb	<5	Be	<10	MgO	25.31
Ga	<3	Sb	Trace	Na_2O	0.27
Ge	<3	Te	–	K_2O	0.14
Cr	30	$S_{tot.}$	3200	P_2O_5	0.07
Zn	10	SO_4	–	H_2O	8.42
Cu	–	TREE	90	Au,Ag,Pt	–

- Contact time: 7 h
- Liquid to solid ratio: 1 to 1

Specifications of the leach liquor are given in Table 3.

3.2. Pachuca column

A pachuca column (volume 1.7 l as shown in Fig. 1) was used in order to implement the "resin-in-pulp" operation (Abramov and Brodski, 1993; Skorovarov, 1975; Laskorin et al., 1977; Tatarnikov and Abramov, 1993; Tatarnikov and Zvonarev, 1995). The entries 8 and 9 were used for agitating the mixture of pulp and resin by air. The air is introduced by entry 1 for holding up the mixture of pulp and resin from tee 12 and this mixture is flushed on the screen from exit 2. The openings of screen are designed for passing the particles of pulp but not resin beads which slide on the surface of screen and return to the column. The pulp

Table 3
Specification of leach liquor

Specification	Amount	Specification	Amount
pH	1.3	SO_4^{2-} (g/l)	55.58
EMF (mV)*	485	SiO_2 (mg/l)	1820
U (mg/l)	195	As (mg/l)	7
Fe^{2+} (mg/l)	850	Th (mg/l)	<2.5
Fe^{3+} (mg/l)	1150	PO_4^{3-} (mg/l)	Trace
V (mg/l)	65	La (mg/l)	<2.5
Mo (mg/l)	<5	Ce (mg/l)	<2.5
Mn (mg/l)	400	Y (mg/l)	<2.5
Co (mg/l)	32	Recovery (%)	82.7
Free acid (g/l)	31.5		

* Pt versus calomel reference electrode.