Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Desalination 235 (2009) 9–32
DESALINATION
www.elsevier.com/locate/desal

Extraction of uranium from the concentrated brine rejected by integrated nuclear desalination plants

H. Sodaye[a], S. Nisan[b*], C. Poletiko[c], S. Prabhakar[a], P.K. Tewari[a]

[a]*Desalination Division, Bhabha Atomic Research Centre , Trombay, India*
[b]*DER/SESI/LESA, CEA, CEN Cadarache, F-13108 Saint Paul-lez-Durance, France*
Tel. +33 4 42 25 46 28; Fax +33 4 42 25 36 35; email: simon.nisan@cea.fr
[c]*DTN/STPA/LEC, CEA, CEN Cadarache, F-13108 Saint Paul-lez-Durance, France*

Received 3 October 2007; accepted 7 February 2008

Abstract

This work was carried out under the specific collaboration agreement between the Bhabha Atomic Research Centre (BARC) from India and the Commissariat à l'Energie Atomique (CEA) from France. This paper summarises first results of review and research on the possible extraction of uranium from the concentrated brine rejected by integrated nuclear desalination systems, which both partners are currently developing in the two organisations. Three innovative and efficient methods of uranium extraction have been proposed: 1) Resin grafted with calixarene: this method has the advantage of very high selectivity. Its performances, especially for large-scale extraction, still need further R&D and optimisation; 2) Magnetic separations: yet another method with high selectivity, easy separation and affording high degree of material recovery. The method, however, is in developmental stage; 3) Canal system with Braid adsorbents: high selectivity. Appears to be feasible in conjunction with existing technology. It would nonetheless require large amounts of adsorbents and adequate infrastructure.

Keywords: Brine valorisation; U extraction; Nuclear desalination

1. Introduction

It is now generally agreed that in order to meet the tremendous water shortages in many regions of the world, seawater desalination, especially by the nuclear systems, could be an economically attractive and low-cost solution [1].

Seawater usually contains sixty elements from the Periodic Table. The brine, rejected by a desalination unit, is a concentrate of all compounds contained by seawater. Table 1 shows a typical composition with some of the elements of interest. Out of these, some are very scarce on land and/or are very expensive. There is thus a strong motivation for extracting these materials.

*Corresponding author.

0011-9164/09/$– See front matter
doi:10.1016/j.desal.2008.02.005

Table 1
Seawater composition

	Cations (ppm)		Anions (ppm)	
Major components	Na^+	10,500	Cl^-	19,000
	Mg^{2+}	1350	SO_4^{2-}	2650
	Ca^{2+}	400	HCO_3^-	140
	K^+	380	Br^-	65
	Sr^{2+}	133	F^-	1.3
			H_3BO_3	260
	Li^+	0.17	I^-	0.06
	Rb^+	0.12	MoO_4^{2-} (as Mo)	0.01
	Cs^+	0.0005		
Minor components	Ba^{2+}	0.03	$VO_2(OH)_3^{2-}$(as V)	0.002
	Zn^{2+}	0.01	PO_4^{3-}	0.07
	Fe^{3+}	0.01		
	Cu^{2+}	0.003		
	Mn^{2+}	0.002		
	In^{3+}	0.02		
	Ge^{4+}	0.00007		
	U^{6+}	as	$UO_2(CO_3)_3^{4-}$	0.00334

Current practice in countries using large-scale desalination is to reject the brine back to the sea. This rejection may lead to a degradation of local fauna and flora unless the concentrated brine is diluted or rejected far from the coast, which would unnecessarily increase overall costs. Extraction of materials and subsequent brine conditioning for surface storage, with almost zero discharge to the sea, would therefore be a more environment friendly option.

Yet another advantage of this extraction will be the reduction of overall costs of the cogeneration nuclear desalination systems since the benefits of a third product would be added.

The methods of material extraction are still in preliminary stages of development but significant progress has already been reported in a previous publication [2].

As outlined in [2], not all the materials contained in seawater are worth extracting unless there are specific requirements (e.g. extraction of uranium). As an important first step, a short list of interesting materials was therefore established. The selection criteria used for this list were: 1) **Economic criteria**: current price, estimated evolution of the market, production cost and abundance on land, 2) **Physicochemical criteria**: formulation of the element in seawater, concentration, reactivity and 3) **Technical criteria**: evaluation of extracting methods from a complex aqueous system.

The resulting list (Table 2) consists of eight different elements. The products would either allow large-scale production of useful materials such as fertilizers or the extraction, in lesser amounts, of some rare materials with high added values and often used in high technologies. To these, we have added uranium for its obvious interest for a durable, self-sustaining nuclear fuel cycle.

In Table 2, annual production calculations are based on the hypothesis of a plant equipped with reverse osmosis desalination system for the la Skhira site in Tunisia [3], producing about 168,000 m^3/d. The recovery ratio of this process is supposed constant at 40% with an availability