

Uranium ISL Operation and Water Management under the Arid Climate Conditions at Beverley, Australia

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Abstract

Heathgate operates the Beverley uranium mine by using in-situ leach (ISL) technology. The arid climate, the highly restricted access to water resources, and the high salinity of the groundwater are altogether quite difficult conditions for performing ISL. Uranium recovery by ion exchange from the very saline lixiviant at TDS up to 25 g/L has been optimized to achieve a reasonable operational efficiency. The management of water balance under extremely restrictive conditions entails the operation of a nearly closed ISL recycle (minimum bleed), process water recycling and reuse, as well as the minimization of liquid waste water volumes (to be disposed into the Beverley aquifer itself). These measures maintain a neutral water balance in the mining horizon and thus, avoid any aquifer pressurization and subsequent excursion of mining fluids outside the ISL mined aquifer area. This control of fluids is confirmed through a comprehensive aquifer monitoring program.

Key words: uranium, in-situ leaching, processing, geochemistry, salinity, water management, ion exchange, Australia

Introduction

The Beverley uranium mine is located on the arid plain between the northern Flinders Ranges and Lake Frome, approximately 550 km North of Adelaide in South Australia. The deposit exists in permeable sands within the confined, highly saline Beverley aquifer, some 125m below the ground surface. Uranium is mined using moderately acidic in-situ leach (ISL) technology. The Beverley mine is operated by Heathgate Resources Pty. Ltd. (Heathgate 2008) in accordance with stringent safety and environmental standards (Taylor et al. 2004, Märten 2005, Märten et al. 2008).

To ensure a sustainable mine operation in all respects and to prevent any significant impacts on the environment, emphasis is placed on (Märten et al. 2008):

- Ongoing exploration in the area,
- Monitoring the hydro-geological / geochemical conditions in the mining area and in its vicinity for optimising water balance and avoiding any migration of mining fluids into the environment,
- Application of a solute transport model (combined within a hydro-geological model) for forecasting groundwater flow and chemical transport conditions in the Beverley aquifer,
- Implementation of innovative techniques for monitoring and managing the reclamation of the aquifer in the abandoned wellfields.

ISL operation and uranium processing

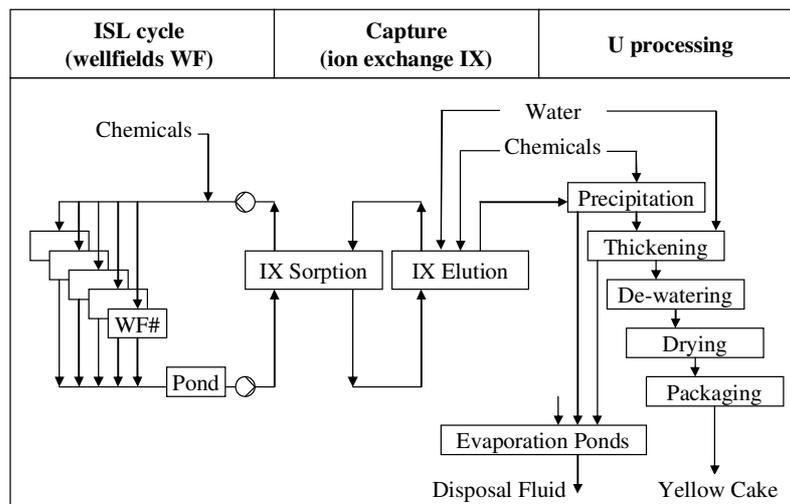
As shown in Fig. 1 schematically, ISL mining and U processing include the following operational areas:

- Closed-loop ISL cycle of the mining fluid (lixiviant) through several wellfields in parallel, each consisting of 14 extraction wells and up to 42 injection wells (operated via pumping huts called well-houses),
- Barren lixiviant acidification (sulfuric acid) and oxidant (hydrogen peroxide) dosing,
- Uranium capture from the pregnant lixiviant using an anionic ion exchange (IX) resin in sequences of two columns (lead and tail columns),
- In-place elution in a two-stage operation,
- Uranium precipitation using hydrogen peroxide,

- Thickening and washing (for removal of dissolved impurities), de-watering, drying, packaging.

The wellfields are a rolling development that move along the (mineralized) paleochannels and can be progressively rehabilitated as completed. Barren lixiviant pH and ORP are adjusted for optimum leaching. The pH is kept moderately acidic (injection pH of about 1.6 to 1.8) thus limiting the specific sulphuric acid consumption to about 5 kg per kg U. The pH is kept low enough to ensure a chemically stable lixiviant (limiting the precipitation of secondary phases) and high enough to limit the dissolution of host minerals (silicates mainly). The ORP of the barren lixiviant is adjusted by hydrogen peroxide addition so that the majority of the iron (typically about 200 ppm) is oxidized to ferric.

Figure 1 Schematic of ISL cycle, capture and uranium processing



The Beverley ore bodies are located in highly saline aquifers with naturally occurring TDS between 6 and 14 g/L. Interfering leaching effects and recycle from uranium processing increases the TDS in the lixiviant up to 25 g/L. The presence of Cl in the lixiviant, up to 6 g/L, limits the capture efficiency of the resin considerably. However, IX operation has been optimized to enable economic U production under these chemical constraints. The ion exchange process consists of three modules each with five IX columns, capable of treating in excess of 300 L/s. Four of the columns in each module are used for capture usually configured as two lead columns and two tail columns. The fifth column is either being eluted or is idle. Loaded resin is eluted in-place using a two stage process:

- Main elution by 1.5 bed volumes (BV) of ~1M NaCl eluant followed by
- Conversion (secondary elution) by 1.5 BV of ~0.1M H₂SO₄.

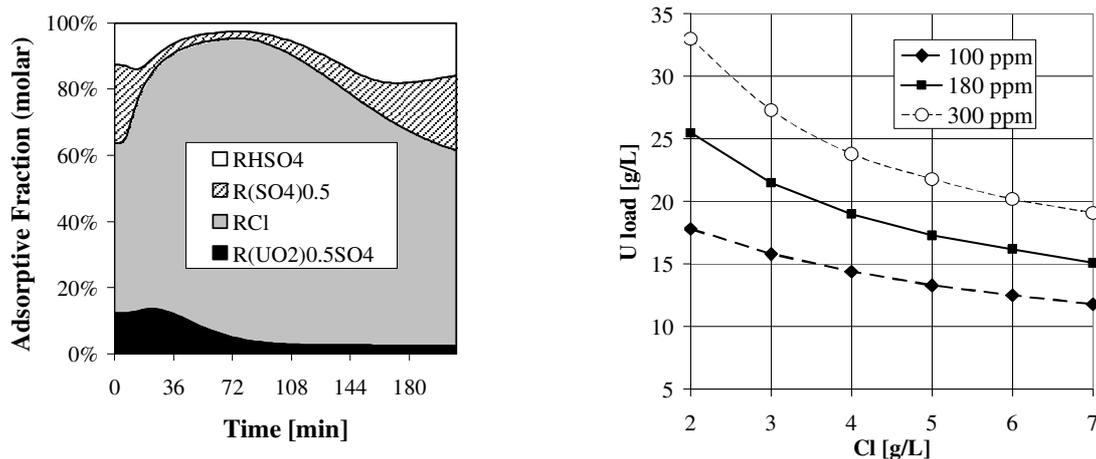
This elution regime is a balance between elution efficiency, time, make-up water consumption and reagent consumption to produce a pregnant solution in excess of 10 g/L U. Finally, uranyl peroxide is precipitated by the addition of H₂O₂ combined with NaOH dosing for pH control, followed by thickening, washing, de-watering and finally drying at low temperature (suitable for UOX precipitate).

Uranium recovery by ion exchange under high-salinity conditions

The typical average head grade at Beverley is in the range from 100 to 250 ppm. The uranium species formed in the acidic lixiviant, UO₂(SO₄)₂²⁻ and higher order complexes, are captured via anionic ion exchange (IX) resins. The efficiency of resin loading is highly dependant on the concentrations of competing anions, e.g. Cl. For Beverley lixiviant conditions, the total IX capacity of the resin, in excess of 1 eq/L, is distributed between the adsorbed anionic species Cl⁻, SO₄²⁻, HSO₄⁻, Fe(SO₄)₂⁻, UO₂(SO₄)₂²⁻, UO₂(SO₄)₃⁴⁻, mainly. Under equilibrium conditions, the actual load by individual anions depends on the specific affinity of the resin as well as on the concentration vector in the liquid phase. Experimental studies (batch and column) were performed in conjunction with 1D reactive transport

calculations with PhreeqC (Parkhurst 1999) used as subroutine for simulating the adsorption conditions based on thermodynamics (with equilibrium constants for resin adsorption adjusted to the experimental affinity data for the resin used). These investigations have shown the actual resin load distribution of the above species for the processing stages sorption and elution (example in Fig. 2, left) as well as the dependence of resin load on Cl concentration in the lixiviant (Fig. 2, right). The calculated data shown in Fig. 2 reproduce real conditions quite well.

Figure 2 Species load kinetics during two-stage elution (left) and resin load capacity for uranium as function of Cl concentration in the lixiviant for 3 given U grades in the lixiviant (right)



The main conclusions for IX operation under the constraint of high Cl concentrations in the lixiviant and minimum consumption of process water (in particular make-up water for elution) include:

- The difference (Δ) of U grades in the pregnant and barren lixiviant on the one side, and the difference (δ) of U resin load before and after elution (loaded vs. de-loaded resin) on the other side; these have to be balanced reasonably to achieve most economic recovery.
- Under current ISL conditions of nearly 6 g/L Cl in the lixiviant (worst case of leaching in Beverley South at highest Cl concentrations in the natural groundwater), typical values are: $\Delta = (125 - 30)$ ppm; $\delta = (15 - 5)$ kg/m³.
- It is not the maximization of both Δ and δ by minimizing the U grade in the barren lixiviant or minimizing the resin load after elution, but the optimization of these process characteristics leading to the most economic recovery (at minimum water consumption).

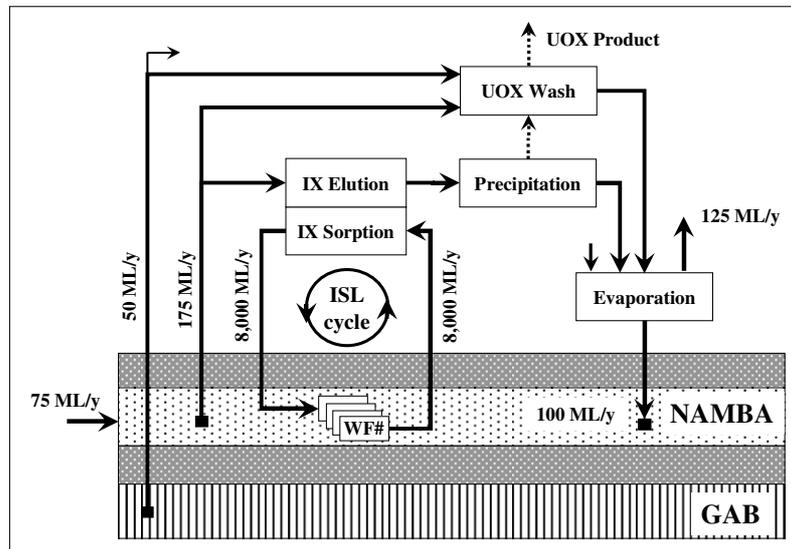
Water management of the ISL mine Beverley

The mine is located in an arid region, where the temperature in summer regularly exceeds 40°C, with average mean maximum temperatures of 30°C in the summer months and 15°C in the winter. The average annual evaporation is around 3,000 mm against an average (highly variable) annual rainfall of only around 100 mm. Consequently, there is no access to surface water for the mining operation.

The plant and aquifer water balance is one of the major challenges in operating the Beverley mine due to the lack of available water of suitable quality, and a limited liquid waste disposal capacity. Water use is kept to a minimum, with emphasis on conserving high quality water supplies. Disposal volumes are also minimised. The water used for mine operation and uranium processing is drawn from two main sources: the Namba Formation (mined) aquifer, and the underlying Great Artesian Basin (GAB) aquifer, separated from the Beverley aquifer by a thick clay layer. Despite the poor quality of water from the Namba Formation aquifer, 175 ML/y is utilised as crude process water (for first wash of the precipitated product, make up of eluant solutions, and plant wash-down water). Relatively high quality GAB water use is highly regulated (current licence conditions allow 57 ML/y). It is used sparingly for final washing of the precipitated product, feed to the potable water reverse osmosis plants, and drilling mud make-up water. Each of the items above returns water to the liquid waste stream. Liquid waste is

disposed of through injection into previously mined sections of the Beverley aquifer. Due to the hydraulically bounded and confined nature of the aquifer, liquid waste injection must be balanced by groundwater extraction in order to maintain relatively stable groundwater pressures within the receiving aquifer. In order to meet this neutral water balance requirement, liquid waste volumes are reduced through evaporation prior to injection into the aquifer, cf. Fig. 3.

Figure 3 Schematic of water balance at Beverley with reference flow rates



The mining aquifer at the Beverley Mine was proven to be confined during the EIS (Environmental Impact Statement) process (Heathgate 1998). Control must be maintained of mining fluids within the Beverley mining aquifer to ensure no excursions occur laterally outside of the mining area. Flows in and out of the wellfield are constantly recorded and regularly analyzed to ensure a neutral water balance is maintained. A rigorous monitoring program (including a monitoring well ring surrounding the mining area) demonstrates that the mining and disposal fluids remain under control. To better enable the tracking of fluid movements Heathgate has developed a hydrogeological model of the Beverley Sands. This is the latest in advanced technology and provides a diagrammatic map of the current flow paths and in addition serves as a prediction tool. This tool assists Heathgate in demonstrating the sustainability of current and future operations at Beverley.

Summary and conclusions

Heathgate continues to operate and develop the Beverley ISL mine in a sustainable manner, incorporating innovative mining techniques well adjusted to cope with the extreme arid climate conditions as well as the high salinity of the ISL mining fluid. An efficient system of water management on the basis of a sound understanding of the local hydro-geological structure on the one side and the technological conditions on the other side has been implemented. Heathgate has developed and operates a leaching and processing system well adjusted to the specific site conditions and that complies with all regulatory requirements and that has an acceptable impact on the environment.

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