8th Uranium Event

ALTA 2012 URANIUM CONFERENCE

MAY 31-JUNE 1 2012
BURSWOOD CONVENTION CENTR
PERTH, AUSTRALIA

ALTA
ALTA Metallurgical Services
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PROCEEDINGS OF
URANIUM SESSIONS AT ALTA 2012
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URANIUM HEAP LEACHING FORUM

URANIUM HEAP LEACH MODELING

By

[1]François Geffroy & [2]David Dixon

[1]Mining BG, Areva, France
[2]University of British Columbia, Canada

Presenter and Corresponding Author

François Geffroy
francois.geffroy@areva.com

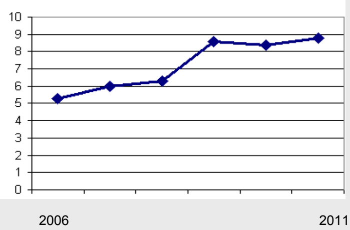
A sustained production growth

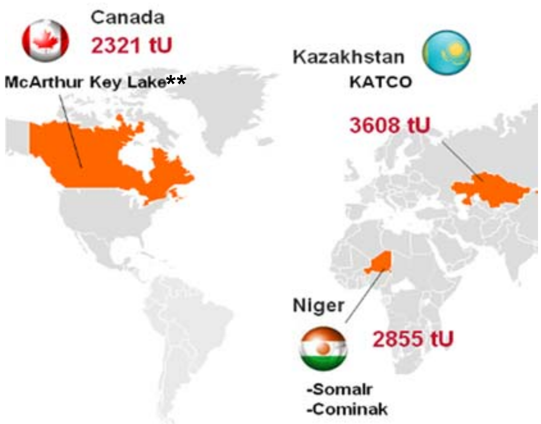
N# 2
world producer in 2011

8790* tones of uranium in 2011

+ **9%** since 2010 (despite closure of McClean Lake mine)

AREVA production growth, ktU





3 countries with 4 operating mines in 2011

*Accessible share of production, includes 6tU produced in France
** Operated by CAMECO

Heap leaching issues

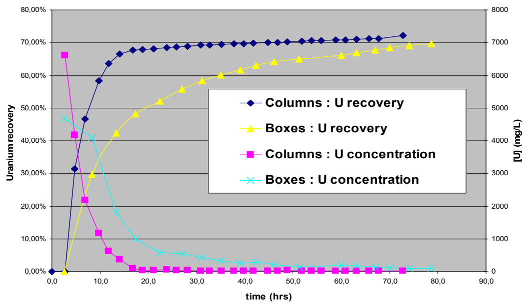
- **Ore preparation**
  - **Crushing mesh ?**
- **Agglomeration**
  - **How much water ? acid ? binder ?**
- **Stacking**
  - **Heap dimensions ? Target density ?**
- **Leaching**
  - **Irrigation pattern ? Flow ?**
  - **Acid concentration ? Oxidant ?**
  - **Leach time, number of cycles ?**
  - **Expected recovery ? Acid consumption ?**

Column and crib tests

- Operating conditions optimisation
- Scale-up effect analysis

Agglomerated ore at Somaïr

Imouraren column tests (4m x 0,24m)



Cribs Somaïr (3m x 3m x 6m)

Heap Leach Modeling stakes

Stakes

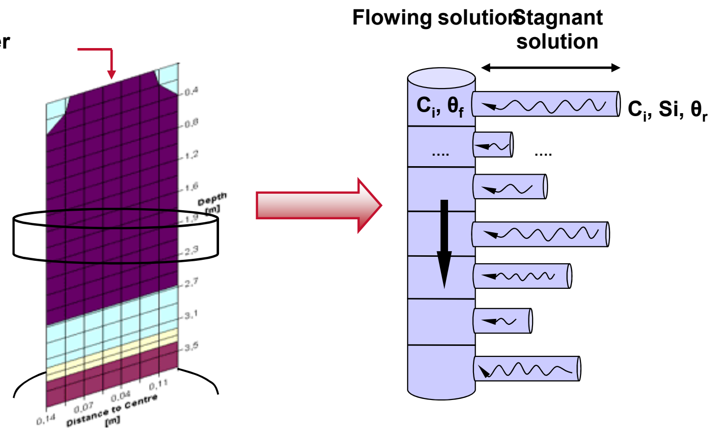
Optimising production and costs
Around 45% of U reserves involve heap leaching

Objectives

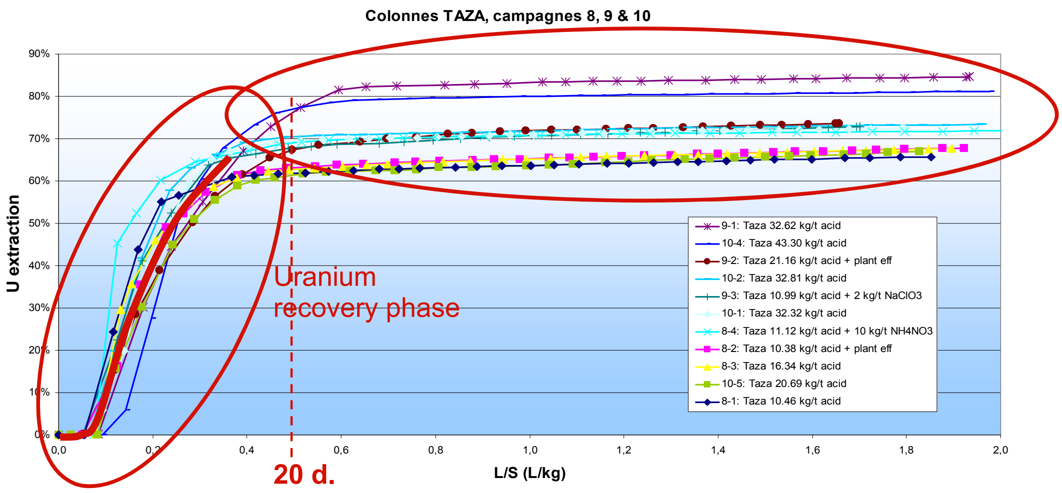
1. Understanding the physics (flow, chemistry, transport) at various scales
2. Predicting the recovery through simulations → Optimising the operational parameters
3. Coupling column leach tests and modeling to reduce the overall number of tests

HeapSim2D model

- ▶ **Hypotheses**
  - ◆ **Homogeneous medium**
  - ◆ **Cylindrical section under a dripper emitter**
  - ◆ **No plugging, no subsidence**



Column leach tests data analysis



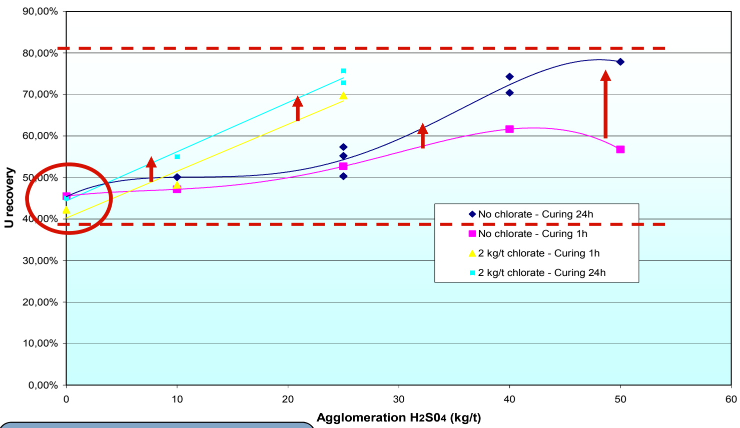
- ▶ **Whatever the agglomeration conditions, leaching is practically done at L/S = 0,5 (20 d.)**
- ▶ **Initial slopes are similar → rinsing phenomenon**
- ▶ **Reactive agglomeration is a key step of heap leaching**

Agglomeration tests

- **Objective**
  - **Knowing the initial state before irrigation**
  - **Understanding the chemistry (kinetics and equilibrium)**
  - **Better characterisation of the initial ore**
- **Protocol**

H_2SO_4 (kg/t)	0, 10, 25, 40, 50
$NaClO_3$ (kg/t)	0, 2
Curing time (h)	1, 24, 48
Temperature (°C)	50, 60
In-depth chemical analyses	U, pH, Eh, Fe, major metals, mineralogy

Main results



- The majority of Uranium is dissolved after agglomeration
- The oxidation ratio in the ore is **45% U(VI) + 55% U(IV)**
- Curing time has a positive effect (concentrated acid medium). Especially at high acidity.

Analysis

- **At low acidity, there is not enough Fe^{3+} in solution for oxidant to influence U recovery**
- **At high acidity, a longer curing time helps dissolving enough Fe^{3+} from the gangue, to increase U recovery.**

Chemical model

- Only 6 « minerals »
  - U(IV) → UO_2
  - U(VI) → UO_3
  - Fe(II) → FeO
  - Fe(III) → Fe_2O_3
  - gangue → MO
  - Carbonates → MCO_3

HYPOTHESES

- UO_3/UO_2 = 45%/55%
- Fe_2O_3/FeO = 45%/55%
- Gangue = Si + Al

- A single standard dissolution rate equations for each

ex gangue : $MO + H_2SO_4 \rightarrow MSO_4 + H_2O$

4 calibrated parameters

$$r_{MO} = \rho_b k_{MO} \exp\left[-\frac{E_{MO}}{R}\left(\frac{1}{T} - \frac{1}{T_{0,MO}}\right)\right] c_{Acid}^{n_{MO}} \left(c_{MO} - f_{MO} c_{MO,0}\right)^{\varphi_{MO}}$$

Transport parameters measurement

✓ Model of Van Genuchten and Mualem for unsaturated flow in a porous media

❑ Measured and calibrated parameters

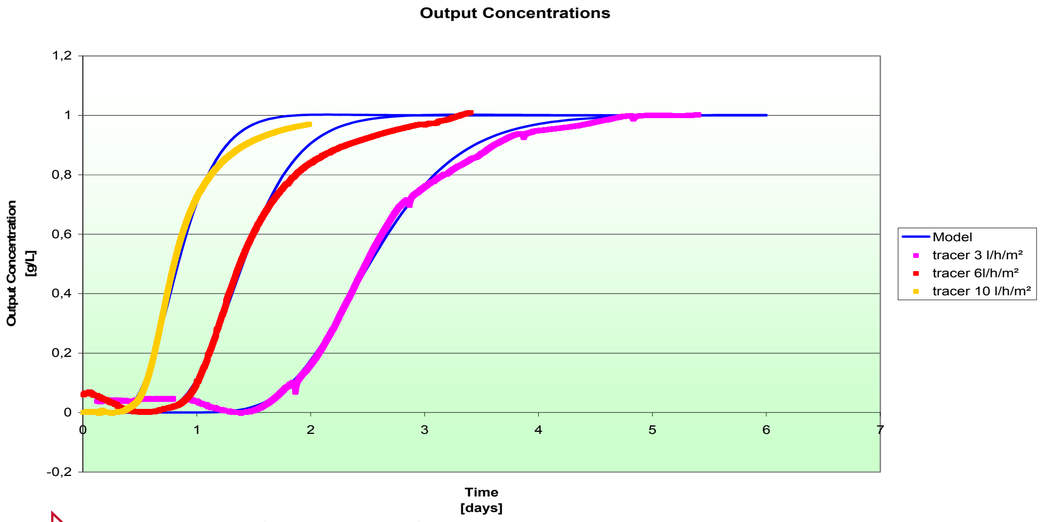
- The ore reaction to flow variations provides the flow parameters
- Tracer study
- Allows modeling at any scale

Dedicated column, equipped with tensiometers and scale

Data

Tracer tests

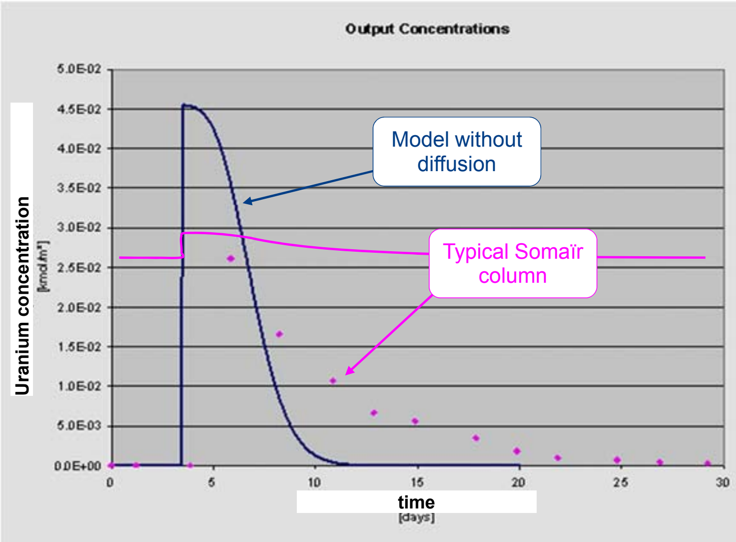
- KCl used as a tracer to calibrate dispersion at various flowrates



⇨ **Validation of measured flow parameters**

Influence of diffusion effects

- **Diffusion effects taken into account within the model**



- Uranium recovery is slower than expected with a rinsing model
- Uranium is however almost totally dissolved initially
- Evidence of diffusion, unusual in heap leaching
- Hypothesis strenghtened by the presence of clay (~15%)
- *Possible sorption of U(VI) could explain this result*

Model data

measured

calibrated

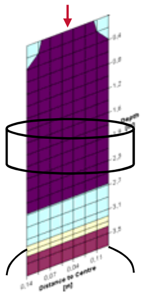
Set by user

MODEL PARAMETERS

- **Kinetics**
- **Transport**
- **Numerical parameters**

INPUT DATA

- **Heap geometry**
- **Ore composition**
- **Initial operating parameters**
- **Parameters variation through time**



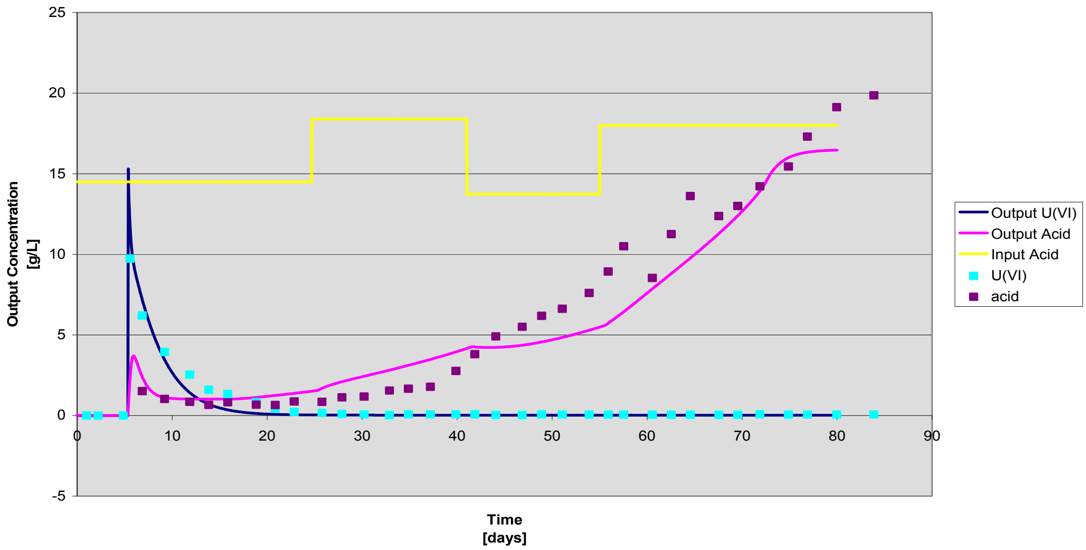
HEAPSIM 2D

OUTPUT DATA

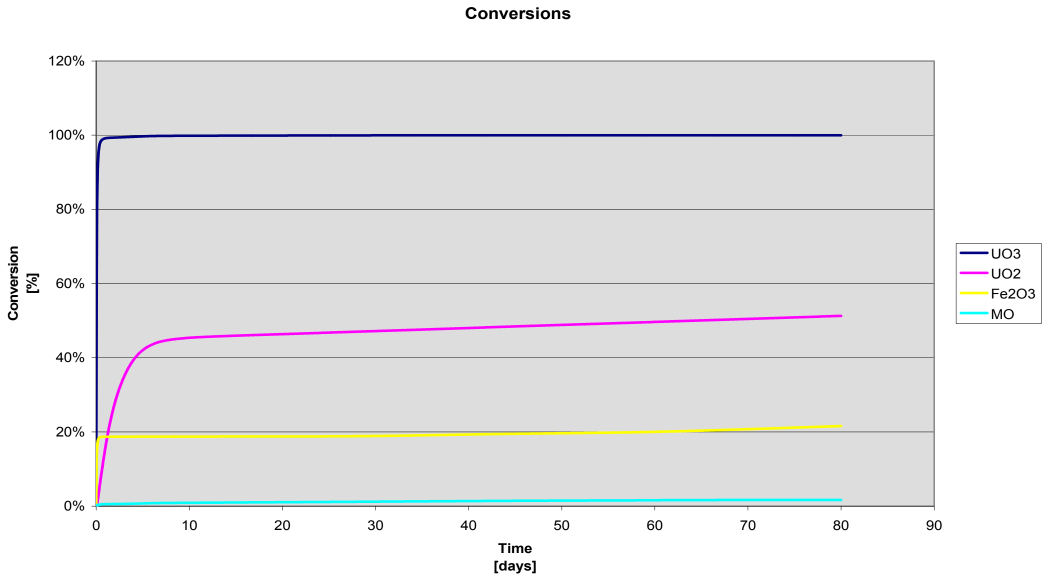
- **Concentrations**
- **Recoveries**
- **Cumulated effluent**
- **2D slice of a column**

Final calibration of the model

- **Effluent concentration compared to column data**

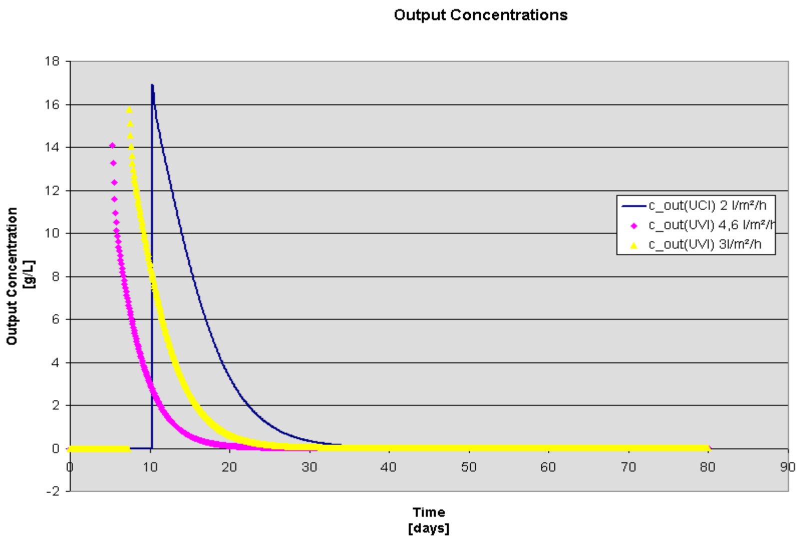


Elements dissolutions



Elements recovery

Irrigation flowrate study



- From a modelling point of view, the faster the flow, the better
- From an operational point of view, plugging issues limit the maximum flow to around 3 l/m²/h

Conclusion

- **Transport mechanism are confirmed**
  - VGM parameters successfully apply to leaching column simulations
  - Capillary pressure is high enough to rapidy balance horizontal flow. Flow is pseudo-1D up to 30 cm dripper spacing.
  - Dispersion and diffusion have a significant effect on U recovery time
  - Uranium recovery from the heap is mainly a transport issue
- **Chemistry is better understood**
  - Maturation should be priviledged. Irrigation almost stops dissolution reactions.
  - [Fe^{3+}] is very dependant on acid (high clay content) and needs to be precisely monitored on site
  - Acid typically dissolves 1-2% of gangue. Highly dependant on agglomeration conditions (limited by using one single gangue mineral)
- **Column leach simulations will be used**
  - **As a complement to column leach experiments during ore studies**
  - **On site to follow production and anticipate variations on uranium concentration in PLS**