Measured and computed solute transport behaviour in the saturated zone of a fractured and slightly karstified chalk aquifer

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Outline

- Results from tracer tests in a fractured /slightly karstified chalk aquifer
- Experiencing two ways for modelling flow and solute transport with the ‘Hydrogeosphere’ code (Therrien et al., 2010)
- Case study: calibrations/simulation of the tracer tests
- Advantages and perspectives
Results from tracer tests in a fractured /slightly karstified chalk aquifer

- 35 tracer tests distributed between 11 sites:
  - main objective of studying the local transport of solute contaminants
  - measured breakthrough curves show different behaviour linked to the coexistence of a porous matrix and fractures in the chalk aquifer
  - some of the fractures have been enlarged by dissolution so that the aquifer is often considered as slightly karstified
  - a first classification with 3 kinds of breakthrough curves
Results from tracer tests in a fractured /slightly karstified chalk aquifer

- dominant advective component, narrow and symmetrical breakthrough curves
- solute transport along solutionally-enlarged fractures
- very high velocity of tracers (between 10 and 110 m/h) for distances between 5 and 130 m for any type of tracer

**Potassium**
- Transport distance: 93 m
- Restitution rate = 8%

**Iodide**
- Transport distance: 54 m
- Restitution rate = 1%
Results from tracer tests in a fractured /slightly karstified chalk aquifer

- A dominant long term dispersive component and possibly immobile water effects
- At very short times, an advective peak can be sometimes detected
- Result of combined effects of the porous and permeable chalk and of the open fractures.

**Graph: Lithium Transport distance: 110 m**

![Graph showing Lithium concentration over time](image)

- Restitution rate = 3.5%

Modelling groundwater flow and solute transport with ‘Hydrogeosphere’

- REV based PARAMETERS with fracture zones discretized explicitly
  - Fracture zones distinguished by elongated zones of higher conductivity and very low effective porosity to reproduce groundwater velocity contrasts
  - Ask a more detailed discretization with distorted/elongated FE
  - May lead to choose unrealistic values for effective porosity

Model 1
Modelling groundwater flow and solute transport with ‘Hydrogeosphere’

- DISCRETE APPROACH: modelling flow in the individual (discrete) fractures
  \[ K_{\text{fracture}} = \frac{a^2 \rho g}{12 \mu} \]
  - needs to identify the most significant fractures within a location
  - application of the fluid mechanics in modelling the flow in the resulting discrete fracture network
  - challenging issues: needed data about geometry, aperture of the fissures, rugosity, ...

Case study: calibrations/simulation of the tracer tests
Case study: flow simulations with pumping in PW1

Model 1 - Computed plume of Li$^+$
505 hours after injection in Pz3

<table>
<thead>
<tr>
<th></th>
<th>$K$ (m/s)</th>
<th>$n_v$ (-)</th>
<th>$a_L$ (m)</th>
<th>$a_T$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalk matrix</td>
<td>1.10*</td>
<td>0.0068</td>
<td>20</td>
<td>32</td>
</tr>
<tr>
<td>Fractured zone A</td>
<td>2.10*</td>
<td>0.0068</td>
<td>20</td>
<td>32</td>
</tr>
<tr>
<td>Fractured zone B</td>
<td>3.10*</td>
<td>0.0010</td>
<td>30</td>
<td>7</td>
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</tbody>
</table>
Model 2 - Computed plume of Li$^+$ 35 h and 505 h after injection in Pz3

<table>
<thead>
<tr>
<th></th>
<th>$K$ (m/s)</th>
<th>$n_e$ (-)</th>
<th>$a_L$ (m)</th>
<th>$a_T$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalk</td>
<td>$5 \times 10^{-6}$ m/s</td>
<td>0.01</td>
<td>45</td>
<td>30</td>
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<tr>
<td>Fractures</td>
<td>$a = 0.008$ m</td>
<td></td>
<td>1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Computed recovery for Li$^+$ injected in Pz3
Other results for Iodide Pz2-PW1

![Graph showing concentration over time for different models.](image)

**Model 1**

**Model 2**
… Rhodamine Pz2-PW1

Other results for Naphtionate
Pz4 – collecting gallery
Naphtionate Pz4 – collecting gallery

... we need to close this fracture
Lesson

- when different tracer test results are available: calibration can become difficult ... but ... at the end: more reliable (it is not yet the case here)

- combining groundwater flow situations and transport breakthrough curves as calibration targets... is constraining a lot

- can become tricky ... operations should be optimized by inverse modelling procedures

Conclusions and perspectives

Conclusions:
- three main categories of breakthrough curves
- promising results using a discrete approach for representing the fractures
- not a large freedom in calibrating parameters
- an aperture of the order of the millimeter is enough for creating clearly a fast advective peak combined with a long highly dispersive component due to the chalk matrix.

Perspectives:
- Improve and optimize calibration using UCODE_2005 or PEST
- Test on other data sets
- Upscale to the whole aquifer
Thank you for your attention!

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