

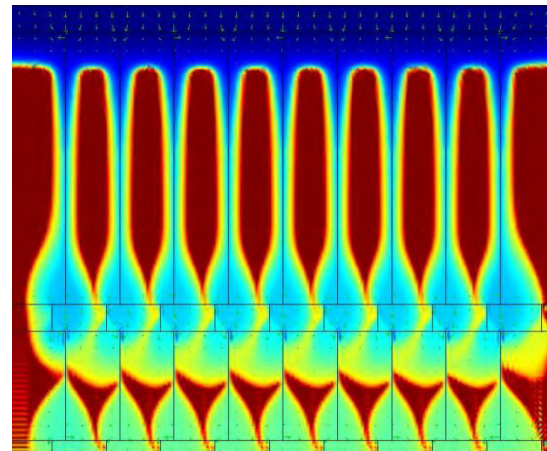
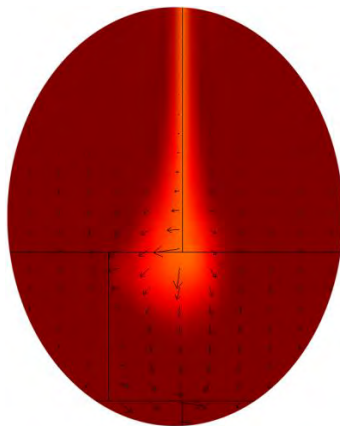
Verification and validation of flow and transport in cracked saturated porous media

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- Cracks, voids and fractures are very common in natural systems
- Flow and mass transport are affected by presence of cracks

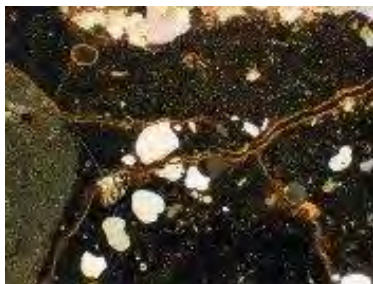
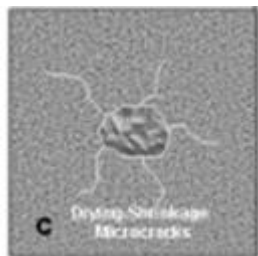


- Our interest is to analyse the effect of cracks in cementitious components which are used to isolate radioactive waste from environment

Nature of cracks in cementitious systems

- Microcracks

- <100 μm
- Spread throughout the concrete
- Usually incorporated in measured bulk properties



- Macrocracks

- >100 μm
- Discrete geometrical features
- Effect incorporated through upscaling or defined as explicit features

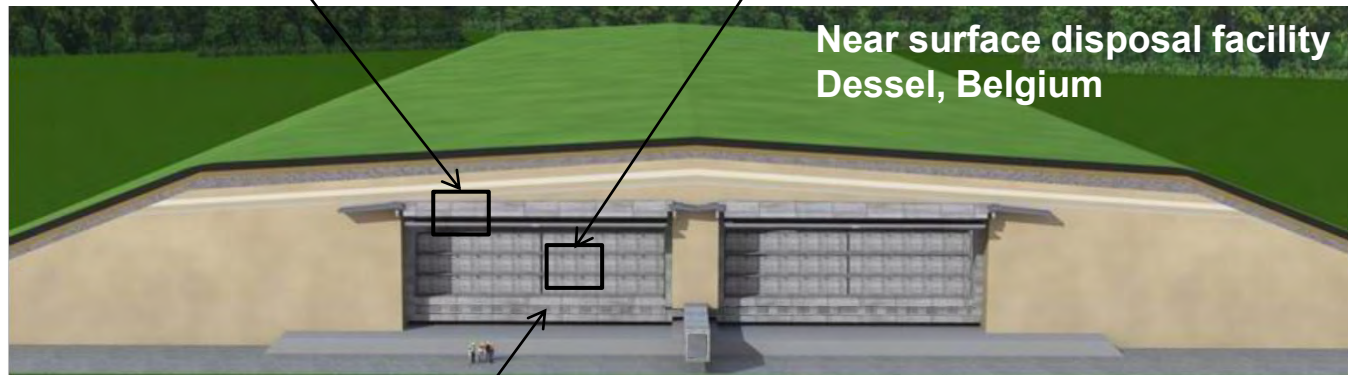


Potential effect of cracks within radioactive waste disposal facility

Cracks in a concrete disposal facility exist in many sizes, locations and time of formation

effect to water infiltration

effect to release from the waste form



effect to sorption properties

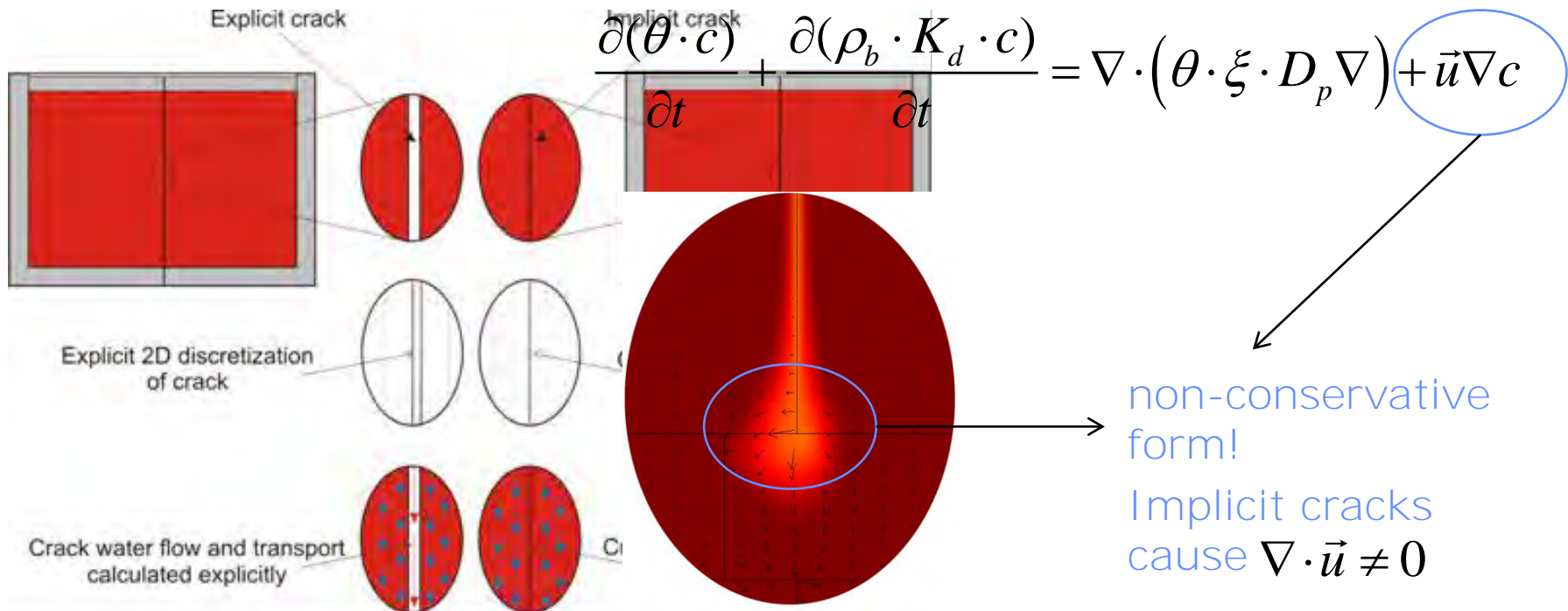
potentially sensitive to

- Crack density
- Crack aperture
- Crack patterns

effect analysed by modelling

- Before actual analysis extensive qualification, verification and validation is required
 - **Qualification:** Conceptual model is set up on the basis of adequate knowledge of the processes involved.
 - **Verification:** Check that numerical model is correctly implemented and that it gives correct solution against chosen conceptual model
 - **Validation:** Check against physical reality

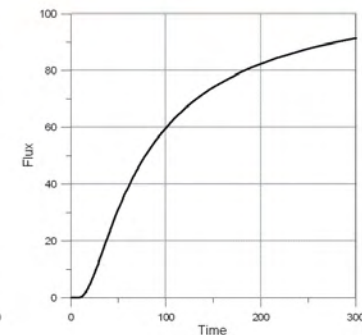
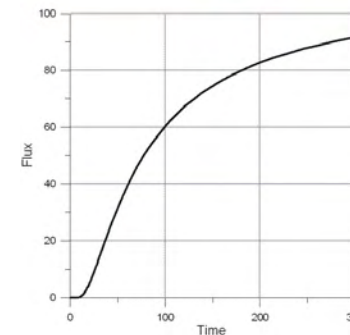
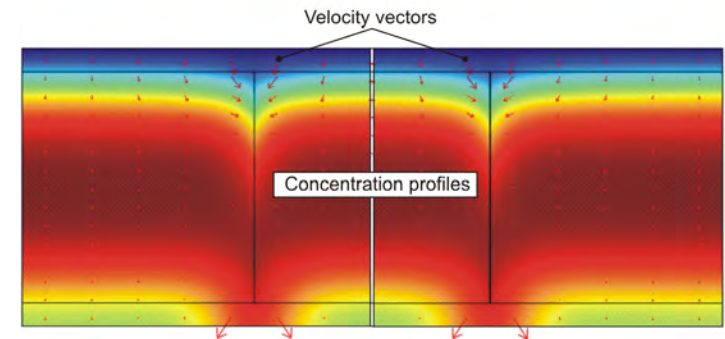
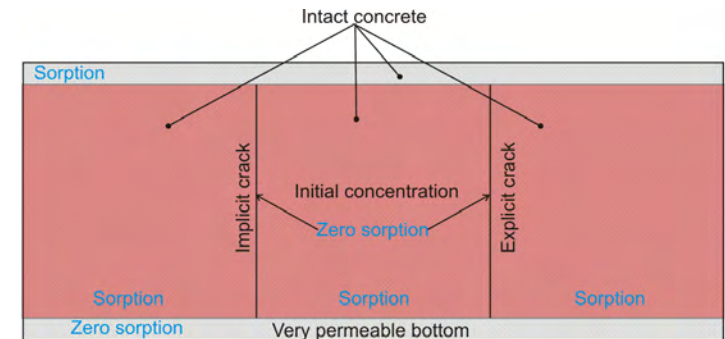
- Argumentation about the hypotheses, assumptions, and parameters used when building the model.



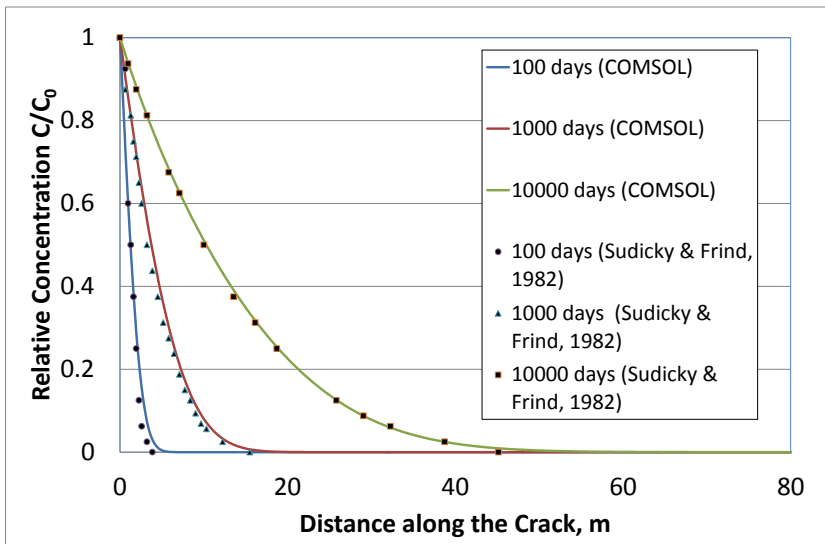
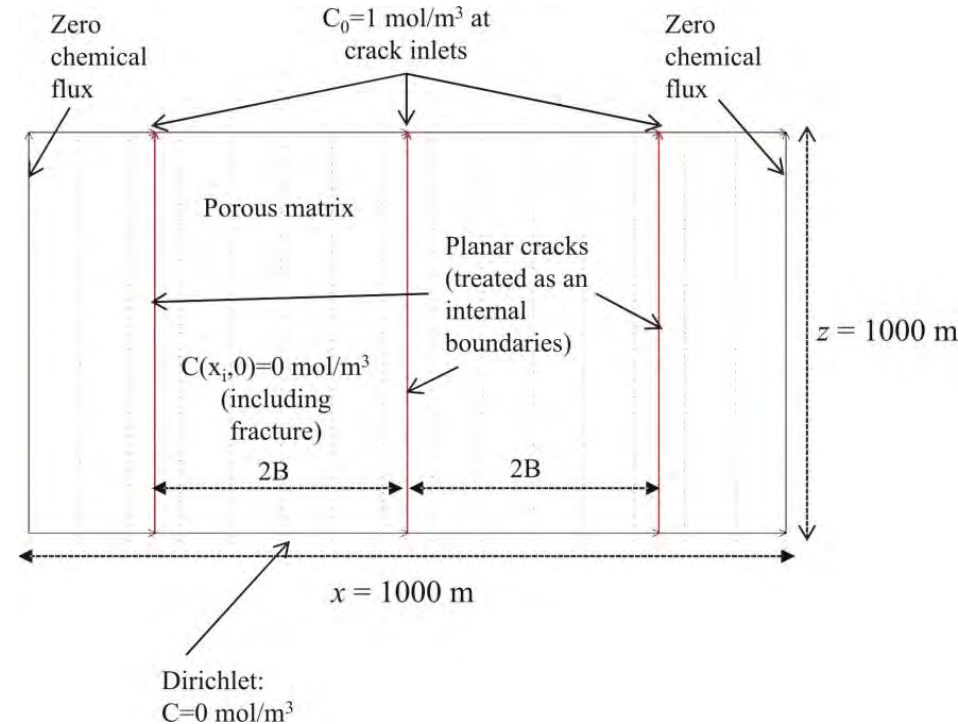
- + Straight forward formulation
- Difficult discretization

- + Better stability
- + Less CPU and memory consuming
- Less straightforward formulation

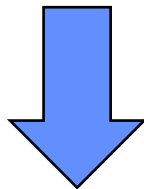
- Simpler cases
 - Comparison to analytical solution
- Complexer cases
 - Benchmarking with alternative numerical solution



- Example: analytical solution of Sudicky and Frind (1982)
 - Multiple parallel cracks in porous media
 - Concentration profiles along cracks recorded in time

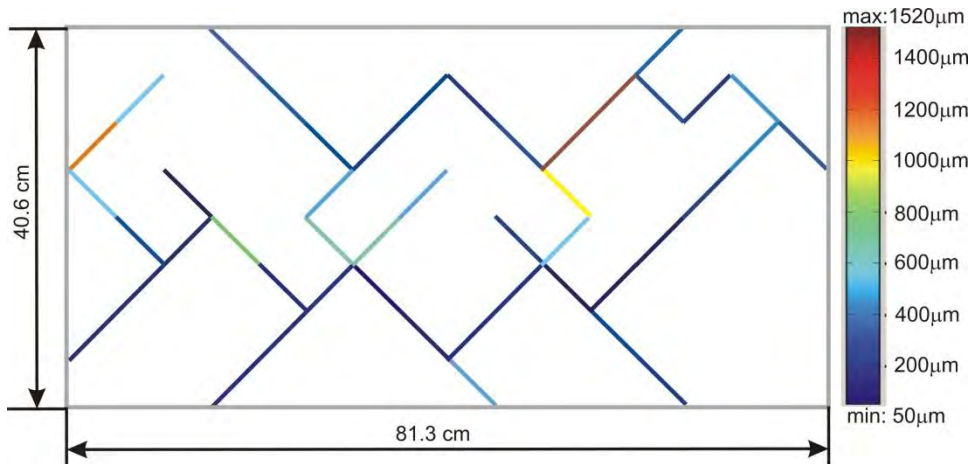


- Validation is performed usually by comparison with experiment
 - Well defined material properties
 - Homogeneity
 - Anisotropy
 - Clear boundary and initial conditions
 - Simple geometry

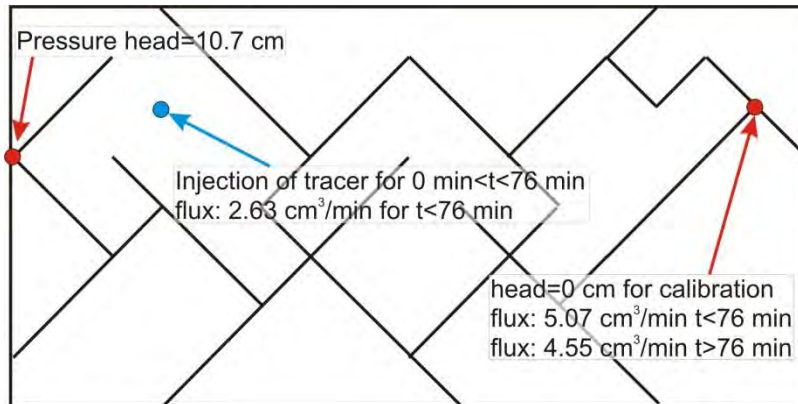


- Numerical solution difficult to verify!

- Experiment with well defined properties (Hull and Clemo, 1987)

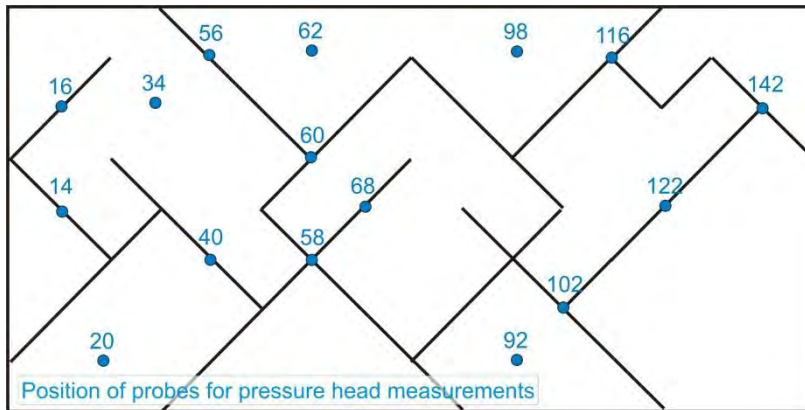


PE with defined pores and homogeneous properties

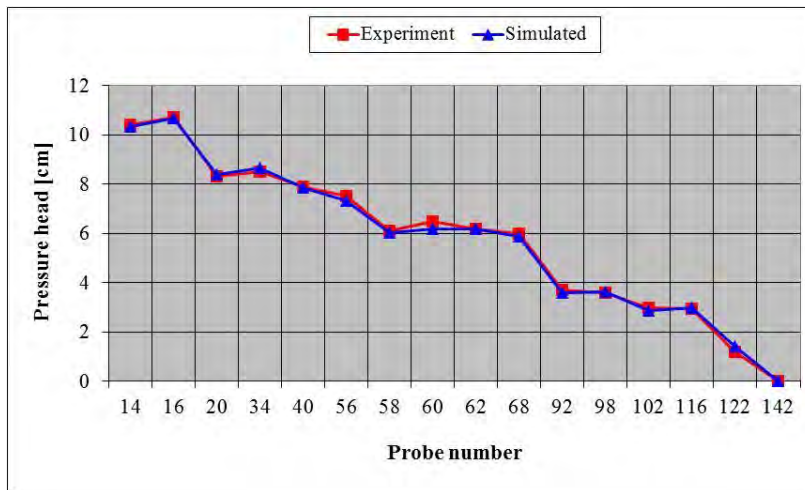


Tracer is visible and with different electrical properties

● Fluid flow

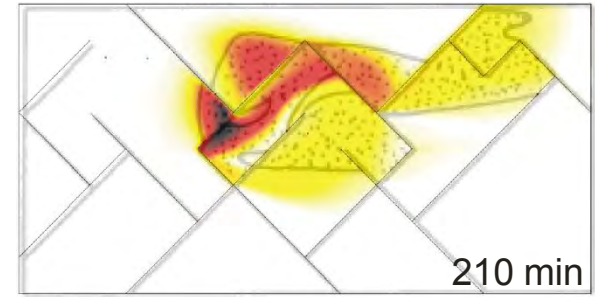
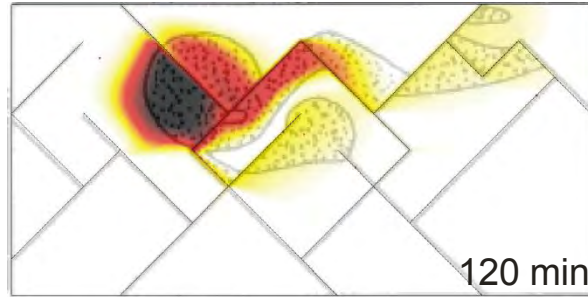
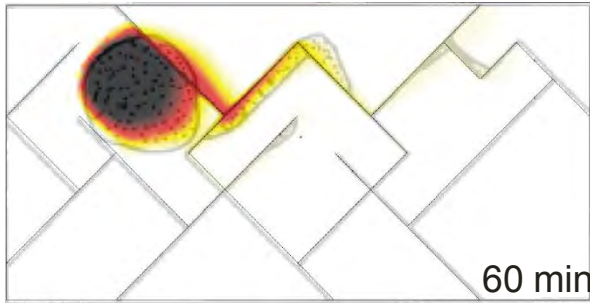


Pressure probes in several locations

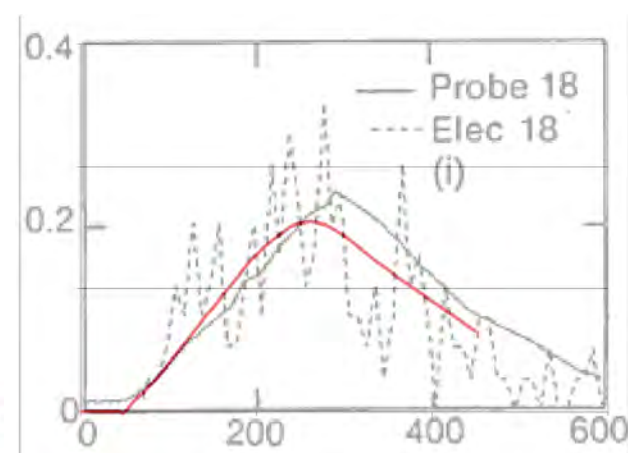
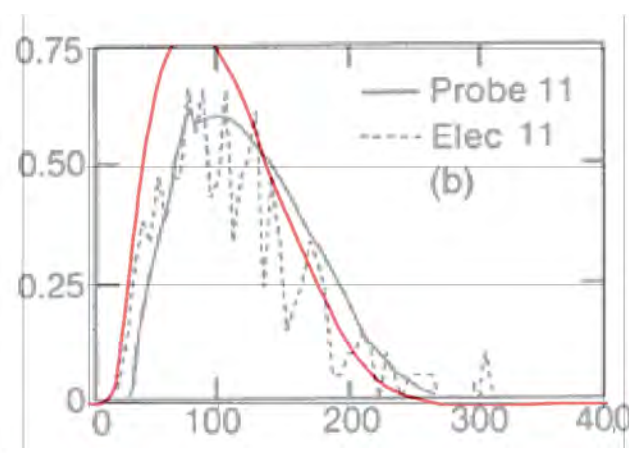
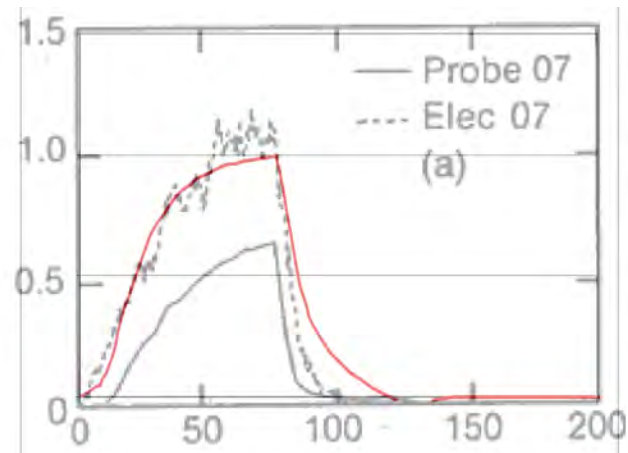


Good agreement between simulation and experiment

● Mass transport



COMSOL picture superimposed to the original picture from experiment



Concentration records in the probes

- Verification and validation of computer codes and models is very important in the modelling procedure
- Validation in the field of porous media transport is difficult because of heterogeneities and anisotropy of natural systems
 - Calibration necessary
- COMSOL Multiphysics is very useful tool
 - Model design and computational efficiency – weak form formulation

This work has been performed as part of the project on disposal of category A waste—short-lived low and intermediate level waste(LILW-SL) – that is carried out by ONDRAF/NIRAS, the Belgian Agency for Radioactive Waste and enriched Fissile Materials. The findings and conclusions in this presentation are those of the authors and do not necessarily represent the official position of ONDRAF/NIRAS. The work presented in this presentation was more particularly carried out as preparatory work to a future license application file for a near surface disposal facility at Dessel to be submitted by ONDRAF/NIRAS to the FANC. Therefore, the results in this presentation have not yet undergone regulatory review nor approval by the FANC. Furthermore, it is not excluded that further developments and refinements of the work presented in this presentation will be included in the future license application file.

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