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Examples of near-field modelling activities in Bel V for supporting the review of safety assessment for radioactive waste disposal facilities

BEL V

filiaal van het FANC | filiale de l'AFCN

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Introduction

- Bel V performs modelling activities in the context of the review of safety assessment of disposal facilities

- The objectives of this presentation are to:
  - Explain the rationale for Bel V, as a TSO, for developing such activities
  - Give some examples of the modelling worked performed and share some of the lessons learned
  - Give some recommendations and limitations for performing such modelling

Outline

- National context
- What is near-field modelling
- Rationale for a TSO for developing models
- Examples of modelling work performed
- Conclusions

National context

- ONDRAF/NIRAS applied in 2013 for a license to build and operate a surface disposal facility for LLW (« category A » waste) to be situated in Dessel
- Bel V collaborates with the Federal Agency of Nuclear Control (FANC) in examining the applicant’s safety case
- ONDRAF/NIRAS continues its R&D program on deep geological disposal for ILW, HLW and spent fuel
  - A clay formation is investigated as potential host rock

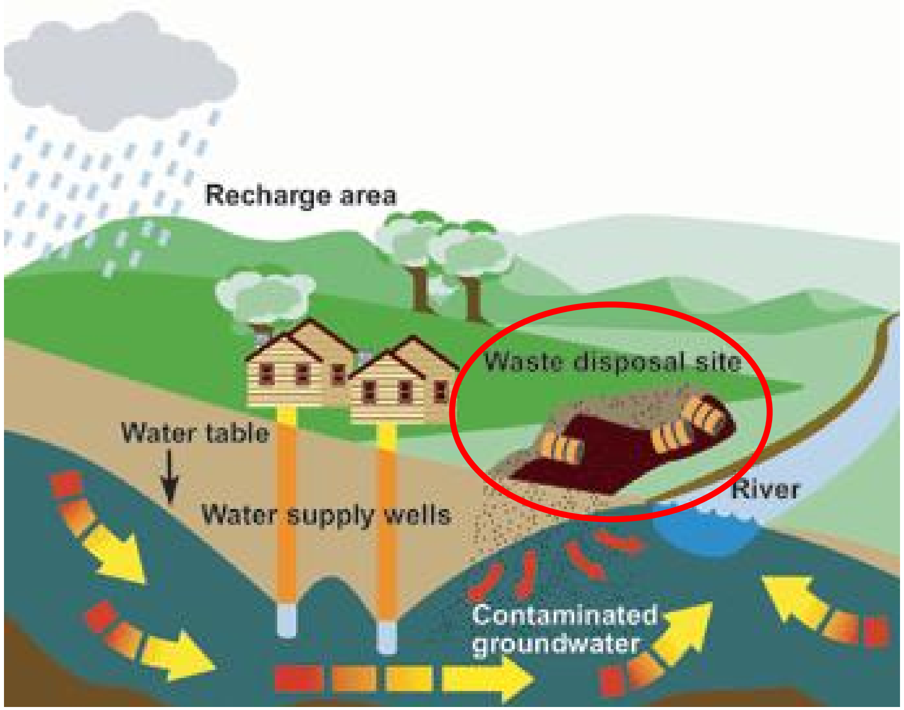
Near-field modelling is considered by Bel V to be important for the safety assessment

- Bel V performs modelling activities:
  - to support the review of the license application for the category A waste disposal facility in Dessel.
  - in international collaboration projects, such as EC Projects or specific collaborations
  - in the framework of its R&D.

- This presentation focuses on near-field modelling but Bel V performs also modelling work in other fields of expertise (e.g. biosphere or hydrogeological models)

Near-field modelling

- The « Near-field » consists of the waste, containers, overpack, backfill and disposal's vicinity



- The output of a near-field model (typically flux of radionuclides at the boundaries) is used as an input for computing the contamination of the groundwater or other geosphere media

Near-field modelling is considered by Bel V to be important for the safety assessment

- Significant time and efforts are dedicated to develop near-field models because:
  - For some types of surface disposal facilities, the safety functions can be mainly fulfilled in the long-term by the waste form and engineered barriers
  - Validation elements, such as natural analogues or experimental results, are difficult to provide considering the long time frames involved.
    Therefore, modelling has to be conducted carefully and the results interpreted with caution

Rationale and benefits for a TSO for developing independent models from the licensee

- Independent modelling supports the review of the safety assessment.
- Indeed, independent modelling allows:
  - To verify the modelling results obtained by the license applicant
  - To better understand the system behaviour (flow and transport of radionuclides) for different scenarios
  - To assess the significance of potential weaknesses identified by reviewers
  - To identify the key parameters, hypotheses and uncertainties in order to focus the review on the critical elements
  - To verify the adequacy of the parameter values and the hypotheses considered in models:
    - Are the parameters and the hypotheses sufficiently representative of the expected behaviour?
    - What is the level of conservatism of the selected parameters and hypotheses with respect to alternative hypotheses?

Rationale and benifits for a TSO for developing independent models from the licensee

- It is also a good way to acquire expertise:
  - There is no better learning than when you get your hands dirty;
  - By raising new questions, it sometimes drives literature reviews;
  - It allows to understand what are the modelling difficulties (e.g. numerical problems) and the current technical limitations of those models;
  - In the framework of the R&D or through international collaborations, modelling is a way to exchange with other organizations in order to compare and discuss about the modelling and safety assessment practices.

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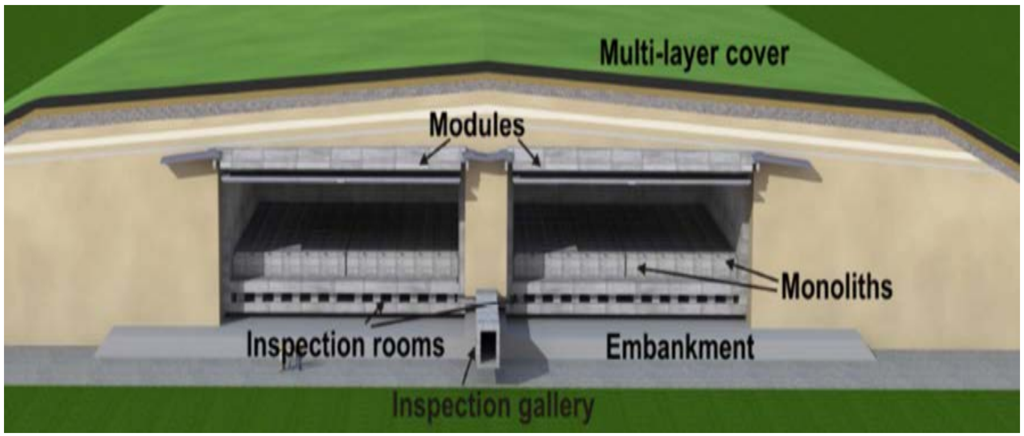
Model verification

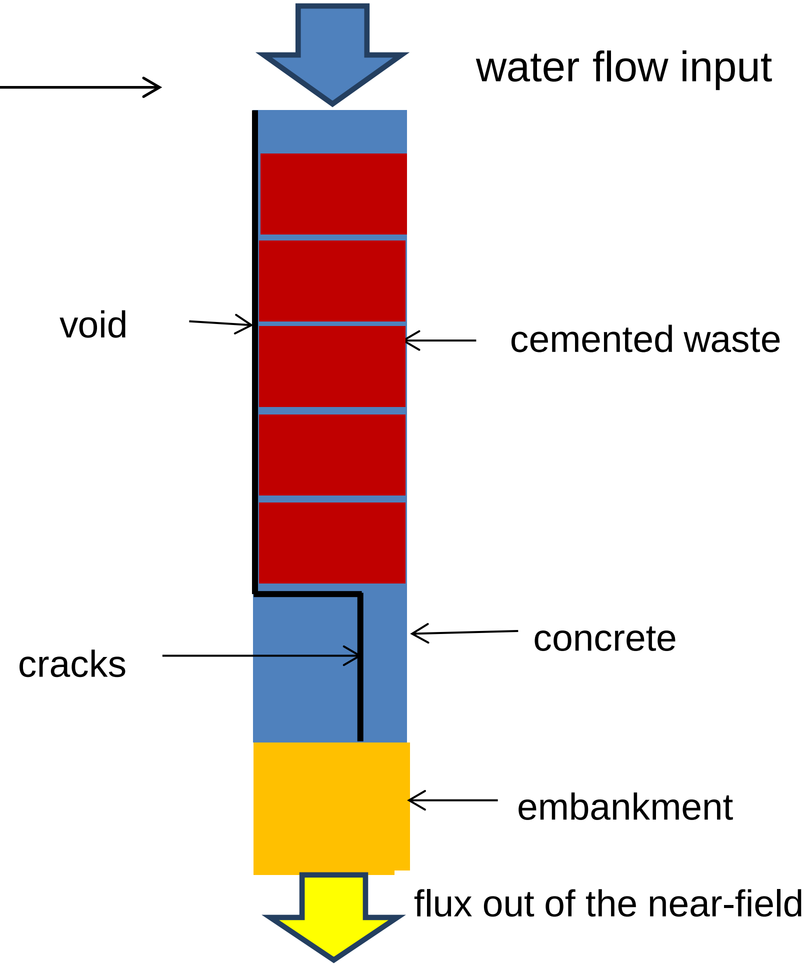
- The ONDRAF/NIRAS reference model for the category A waste disposal project was reproduced independently for some radionuclides
- A different computer program (FEFLOW) was used from the one used by the license applicant
- Outcomes:
  - Verification of the modelling results of ONDRAF/NIRAS with a different code
  - Better understanding of the underlying hypotheses of the model of ONDRAF/NIRAS
  - Expertise building

Study of alternative hypotheses: impact of cracks and voids

Reference model

Illustration of the facility

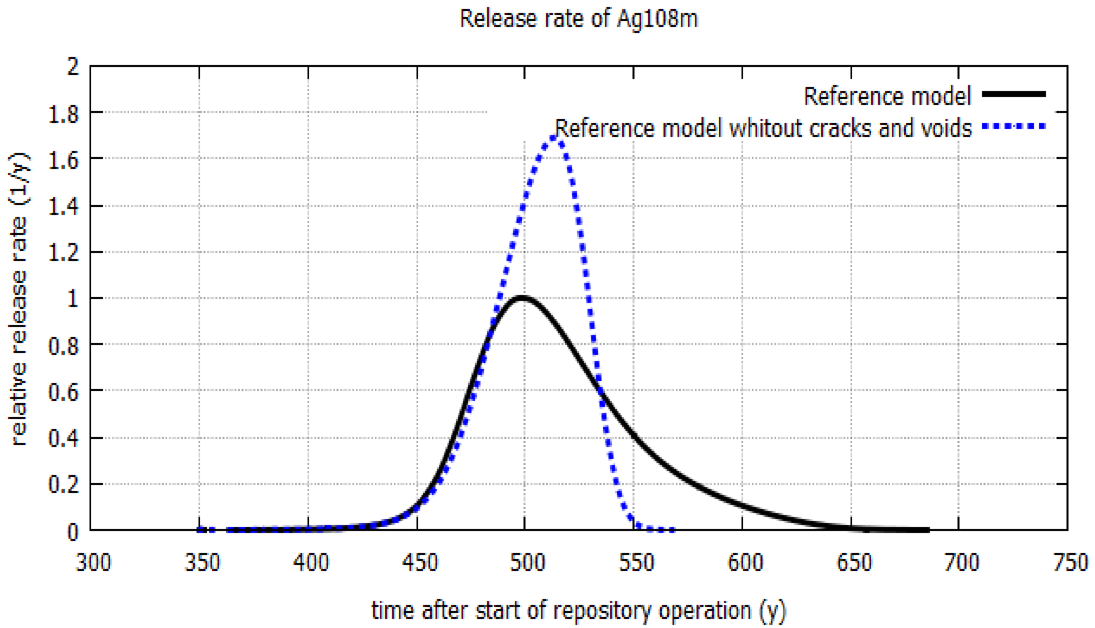




- The impact of cracks and voids on the radiological impact of the reference model was studied by considering « what if » models

Study of alternative hypotheses: impact of cracks and voids

- As an example of a « what if » model, a model without crack and void was considered



- In this example, the maximum release rate is increased by about a factor of 2; which can sound as counter intuitive
  - In fact, the cracks and void give a path so that the water bypass the waste

Study of alternative hypotheses: impact of cracks and voids

- As the impact of the cracks and voids depends, among others:
  - on their pattern (number of cracks and their spacing),
  - on the water flow level,
  - on the radionuclide half-life,
  - on the radionuclide sorption coefficient,

  It is a priori not possible without a complete assessment of the model to determine what constitutes a conservative assumption versus an optimistic assumption

- This example shows that performing independent calculations is a useful tool to support the review of a near-field model

Study of alternative hypotheses: study of chemical degradations

- Chemical degradations of concrete over time can have an impact on the migration of radionuclides
  - Impact on porosity, diffusion properties, permeability, sorption properties, pore water chemistry

- This coupling between flow, transport and chemical alteration can be modelled with a reactive transport code

- Bel V uses the reactive transport code HYTEC to study this coupling

Study of chemical degradations: lessons learned

- Heterogeneous leaching of a 2D cement block was for instance considered with a reactive transport code

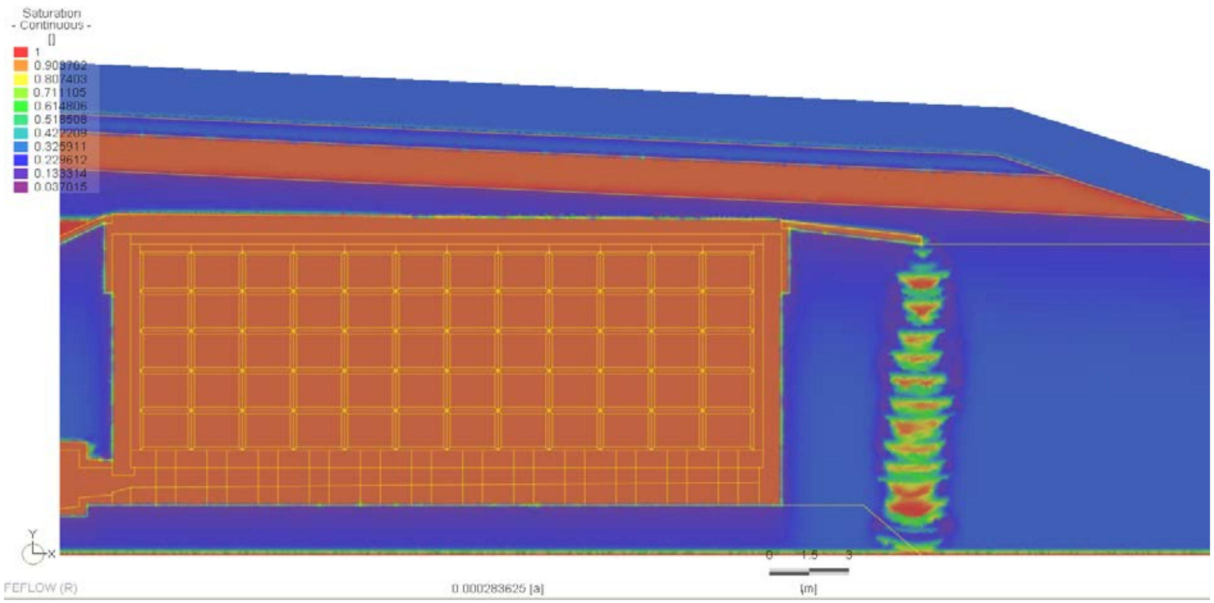
- Lessons learned:
  - Expertise building
  - Cracking pattern can be important to assess the chemical degradation and the heterogeneous alternation could be a phenomenon to consider
  - The results can be difficult to interpret and validate given the complexity of reactive transport modelling
  - Mechanical coupling (e.g. development of cracks) is not supported in HYTEC → no « all in one solution »
- Such modelling should therefore be dedicated to studying specific questions at limited scale , and the extrapolation of these results should be done with care

Evolution of flow and water saturation level

- The repository will be initially unsaturated and its saturation level is expected to evolve after its closure
- The transport of radionuclides is greatly influenced by the level of saturation of the porous medium
- The objective of this modelling was to build an independent understanding of the evolution of the flow and water saturation level in the repository

Evolution of flow and water saturation level

- An unsaturated model was first simulated in FEFLOW



- As numerical problems were encountered initially, several adaptations to the model were necessary:
  - simplification of the geometry of some components,
  - improving the mesh and solver options

Evolution of flow and water saturation level

- This modelling highlighted:
  - the importance of the multilayer cover in the evolution of saturation of the repository,
  - the propensity of the concrete to retain and absorb the water,
  - many computational issues
- An alternative model, taking a two-phase flow into account, was implemented in order to possibly better represent the phenomena at the interfaces between concrete and other material (e.g. sand, gravel)
- This second model gave a different saturation speed
  - The difference between the two models is difficult to explain precisely at the moment, and seems to rely on the mathematical formulation used in the models.

Evolution of flow and water saturation level

- Lessons learned:
  - The heterogeneities of materials properties and the non-linearity of the mathematical formulation leads to numerical issues
  - Due to the time-scales involved it is unfortunately not possible to properly validate these models

Source term modelling

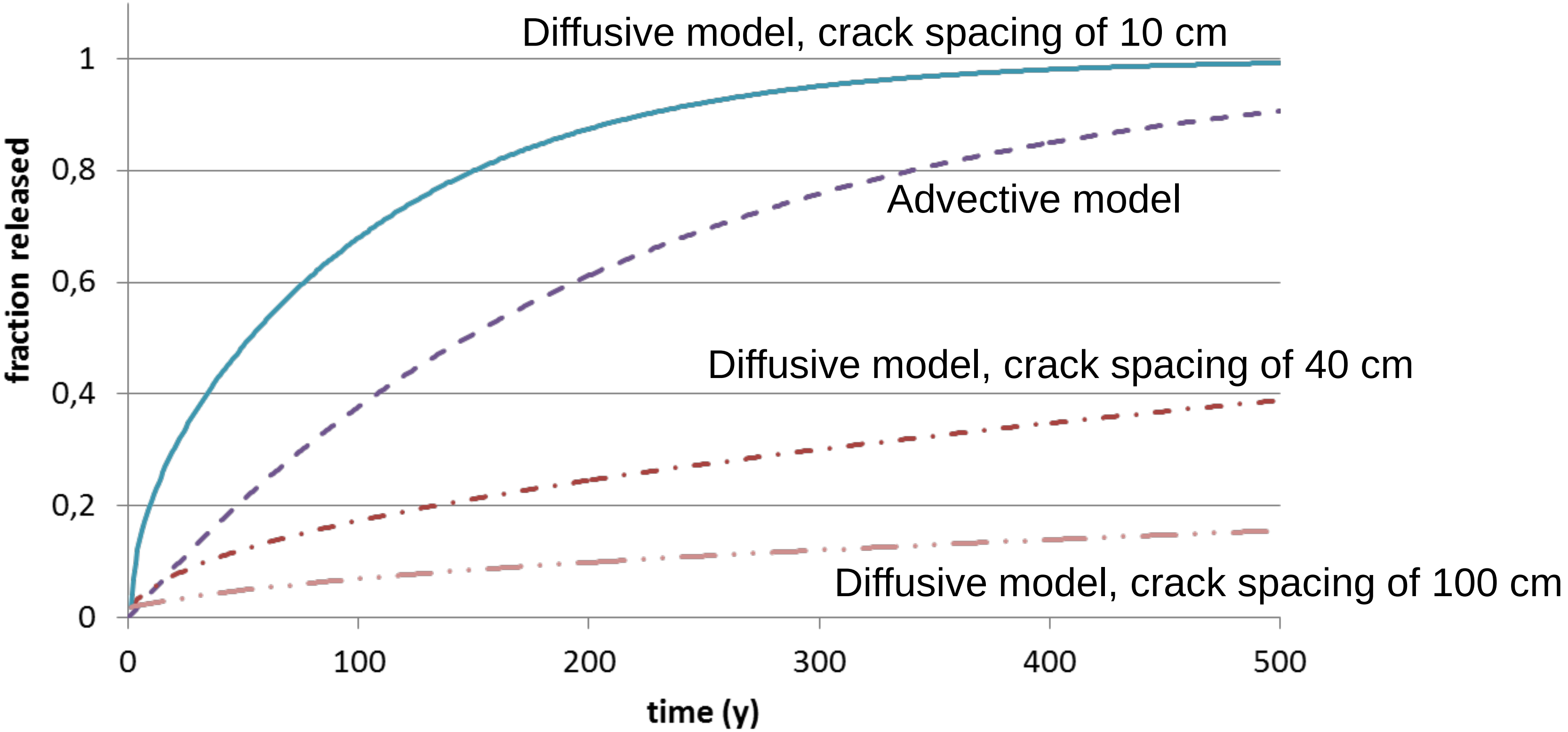
- The source term model was identified as one important part of the near-field model
- The following study was performed to have a range of release rates that was used to compare the different source term models and their level of conservatism

Source term modelling

- After a litterature review, the release rates calculated from the following models were computed using different sets of parameters:
  - A release controlled by a (constant) corrosion rate
  - An advective model: the waste is embedded in a permeable porous media and is transported by advection only
  - A diffusive model: the contaminant must diffuse over a characteristic length and is then instantaneously transported in fractures by advection

Source term modelling

- Example of results:



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Conclusions

- Bel V dedicates significant efforts to develop expertise in near-field modelling as it constitutes a significant part of the safety demonstration of disposal facilities

- This activity was notably useful for:
  - Building expertise
  - Verifying models developed by a license applicant
  - Identifying and analysing in detail potential weaknesses of the models proposed by the license applicant
  - Assessing the level of conservatism of some hypotheses
    - In particular, as it was shown that the effect of some modelling hypotheses might be counter intuitive (e.g. the effect of cracks and voids), independent modelling can be very valuable

Conclusions

- However, there are some limitations:
  - it may become a time-consuming activity
  - the obtained results can only be partially validated given the time-scale involved
  - the results must be interpreted with care and it can be sometimes hard to differentiate a modelling artefact from a potential real phenomenon

- The following basic recommendations for performing such modelling work are given:
  - The objectives of the modelling activities should be clear from the beginning with well-defined safety indicators
  - The stage of literature review should not be neglected
  - A stepwise approach should be followed, i.e. starting with simple models whenever possible

Additional information

Study of alternative hypotheses: study of chemical degradations

- Heterogeneous leaching of cement was for instance considered: