Understanding results of a groundwater transport model for a surface radioactive waste disposal through sensitivity assessment

Matej Gedeon, Bart Rogiers, Katrijn Vandersteen
Belgian Nuclear Research Centre
mgedeon@sckcen.be

Groundwater modeling for radioactive waste disposal
- Estimating radiological impact on aquifer systems
- Long time frames involved (10^5 y – surface; 10^6 y – geological);
- Changing boundary conditions (climate, land cover, hydrology);
- Uncertainties about the source term and future receptors.
- Exact prediction is thus impossible
- Calculating the amount of dilution in the aquifers
  - Using simple models
  - Based on current conditions (reference geosphere concept)
  - Being reasonably conservative
  - But ... how do we quantify "reasonably conservative" ???

Testing conceptual assumptions using alternative models
- Analysing the conceptual model and testing alternatives
- Estimating degree of conservativeness
- Understanding the models behind numbers.

Example: surface rad-waste disposal facility in Belgium
- Future disposal site for low- and intermediate level short-lived radioactive waste in Dessel, Belgium;
- Impact modelled using a transport model (MT3DMS) in a reduced, finely discretized domain coupled to the flow model (MODFLOW 2005 - LGR);
- Predicting concentrations in a hypothetical well

Radiological impact and safety assessment: Model assumptions
- Groundwater flow field:
  - Steady-state
  - Present climate conditions
  - Uniform hydraulic conductivity in all units
  - Water flux through the facility limited (49 mm/y – 16% of recharge)
- Transport model:
  - Spatially and temporally uniform source flux
  - Pumping well receptor:
    - Located at the most adverse location (at 70 m from facility)
    - Zero pumping rate
    - Screen over the entire upper aquifer (40 m thick)
  - No chemical reactions – decay, sorption (done, but not shown here)

How conservative are these assumptions?

Flow model assumptions: Steady-state flow field
- Steady-state is practical for transport modelling
- Small flow-transport link file
- No need to repeat transient solutions until steady-state in transport
- Testing using a transient model using the same parameters, but changing recharge
  - Testing the steady-state solution on 20-years observation record
  - Same transport model ran with the transient flow solution
  - Lower impact achieved

Copyright © 2013 - SCK•CEN - This presentation contains preliminary data for dedicated use ONLY and may not be cited without the explicit permission of the author.
Flow model assumptions: Current climate conditions

- Alternative climate model built using natural analogue recharge (Spain, Greenland)
- Testing various assumptions concerning boundary condition conceptualization including non-existence of a leaky canal
- Warmer climate (slight reduction of recharge)
  - smaller impact, except of canal non-existence
- Colder climate (big reduction of recharge)
  - up to factor 2 higher impact (canal)

Flow model assumptions: Aquitard parameterization

- Three alternative flow models were tested using various parameterizations of the local aquitard
  - hydraulic conductivity distribution based on the CPT prospection
  - uniform hydraulic conductivity value
  - manually delineated hydraulic conductivity zones (based on thickness)
- Both manually (starting values for optimization) and automatically calibrated flow models were used to produce transport solution

<table>
<thead>
<tr>
<th>CPT based</th>
<th>Uniform K</th>
<th>Calibrated K</th>
</tr>
</thead>
<tbody>
<tr>
<td>27 Bq/m³ (1.5 m)</td>
<td>22 Bq/m³ (3.0 m)</td>
<td>28 Bq/m³ (1.2 m)</td>
</tr>
<tr>
<td>45 Bq/m³ (1.0 m)</td>
<td>36 Bq/m³ (1.5 m)</td>
<td>43 Bq/m³ (0.5 m)</td>
</tr>
</tbody>
</table>

- Concentration dependent on estimated aquifer $K$
- Up to factor two higher impact

Flow model assumptions: Flux through disposal facility

- Amount of flux is inversely proportional to the estimated concentration (more water dilutes more)
- Limited sensitivity
  - 0 mm/y -> 22.5 Bq/m³
  - 49 mm/y -> 22 Bq/m³ (reference)
  - 306 mm/y -> 19 Bq/m³

Transport model assumptions: Source flux uniformity

- Reference case: 50% of the total flux was applied for each disposal tumulus
- Higher flux density applied to the smaller western tumulus – conservative, since this tumulus also produces higher impact
- Depending on sector where increased flux occurs lower than reference value is reached
  - left tumulus: up to factor 2 increase
  - right tumulus: up to factor 3.5 increase

Transport model assumptions: Well receptor conceptualization

- Well position:
  - Reference case: Well at the worst location.
  - Considering possibility of well being located anywhere within plume (C>0.1 Bq/m³)
  - Reference value exceedance probability = 0
  - Prob. of exceedance of 1/10 of the reference value = 40%, 50% EP -> 1.6 Bq/m³ (ref.=22)
- Screen length and depth:
  - Reference: entire aquifer screened (40 m) -> vertical averaging of concentrations
  - Testing various screen lengths at different depths:
    - Short screen (1.5 m) -> factor 2 increase, but also factor 200 decrease when placing at different depths
    - Probabilities: for screen <10 m -> probability of not exceeding the reference value is 40%
- Pumping rate:
  - not sensitive, but zero rate is the most conservative (10000 m³/y -> 14% smaller concentration)

Conclusions

- Evaluating the effect of alternative choices and assumptions
- Attempt to quantify the “reasonably conservative”
- Putting the results in perspective of the assumptions
- The work goes on...
Thank you

and

The Belgian Agency for radioactive Waste and Fissile Materials who cooperated closely and financed this work as part of their program on geological disposal of low- and intermediate short-lived waste.