



Probabilistic Safety Assessment for a Generic Deep Geological Repository for High-Level Waste and Long-Lived Intermediate-Level Waste in Clay



AF-Colenco Ltd

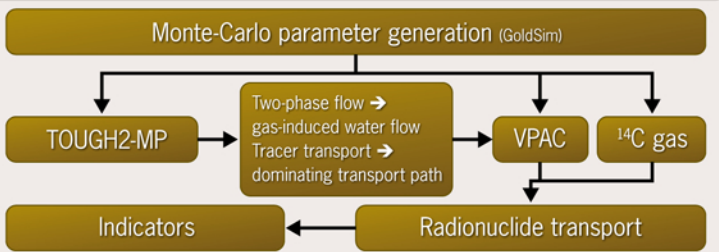
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1 Objective

The aim was to evaluate the long-term safety performance of a deep geological repository for high-level and long-lived intermediate-level radioactive waste in clay. The evaluation is

2 Approach

- Based on probabilistic calculations of the radionuclide release from the wastes and the transport through the host-rock formation and overlying rock
- Relevant FEPs are identified and statistically weighted; parameters are randomly sampled
- Two-step radionuclide release and transport simulation:
 - Two-phase flow and inert tracer propagation with TOUGH2-MP
 - Radionuclide transport for dissolved nuclides with the simulation code VPAC considering decay, ingrowth, solubility limits, time-dependent sorption, diffusion and conductivities; gas-phase transport of ¹⁴C using semi-analytical post-processing



3 Monte-Carlo sampling technique

- Parameters are randomly drawn from five equally distributed discrete values representing very low, low, medium, high and very high values
- 280 simulations = 40 simulations each for seven scenario groups, i.e., reference, cold stage with and without ice cover, 0.1 % leaky waste canisters, seal failures in selected drifts or in main access shaft, and glacial trough

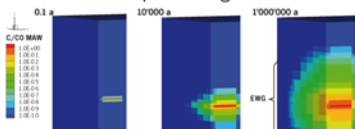
4 Two-phase flow and tracer transport

Simulation features:

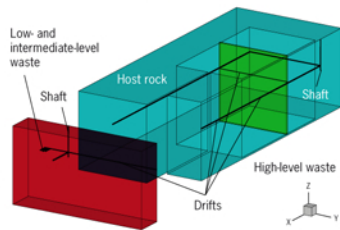
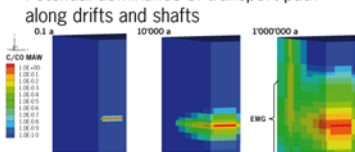
- TOUGH2-MP, EOS7R
- 3D, ~20'000 elements
- Sub-model multiplier technique
- Two-phase flow + tracer
- Computing time per case: ~1 d (4 CPUs)

Tracer concentration for two example runs:

- Dominant transport through host rock



- Potential dominance of transport path along drifts and shafts



Repository system and model layout

Simulation output:

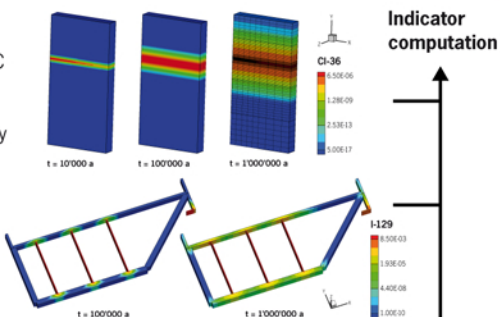
- Tracer distribution
 - improves system comprehension
 - determines dominant transport path
- Water flow from emplacement caverns
 - as source for VPAC computation
- Gas saturation and flow
 - for separate consideration of ¹⁴C transport in gas phase

5 Radionuclide transport

TOUGH2 output

Always: 3D VPAC for dissolved nuclides along host-rock pathway

If potential path along drifts and shafts: Additional 3D VPAC



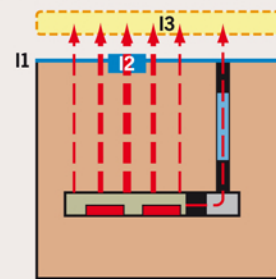
Always: ¹⁴C release in gas phase using semi-analytical post-processing based on TOUGH2 gas flows, appropriate radionuclide source terms and dose conversion factors

based on the probabilistic estimate of three long-term safety performance indicators and their confidence intervals. The work is a fundamental building block within the VerSi project. VerSi concerns the comparison of long-term safety assessments for potentially suitable repository systems, using salt rock and clay as exemplary host rocks.

6 Performance indicators

The safety assessment is based on probabilistic estimates of performance indicators:

- I1** Maximum in time of the radiotoxicity flux integrated over the entire surface of the isolating rock zone (5 km²)
Insignificance criterion: 1·10⁻³ mSv/a
- I2** Maximum in time and space (averaged over 0.01 km²) of the radiotoxicity flux
Insignificance criterion: 2·10⁻⁸ mSv/(m²a)
- I3** Cumulative radiotoxicity release = flux integrated over time (10⁸ a) and space (5 km²)
Insignificance criterion: 10⁸ times the radiotoxicity at containment time, here 6·10⁻⁴ mSv



7 Results

We analyzed the statistical behaviour of the three performance indicators, mainly their median and 95 percentile and respective confidence intervals, in relation to the insignificance criteria. Values below the insignificance criteria are considered zero for the safety assessment.

Indicators I1 and I2:

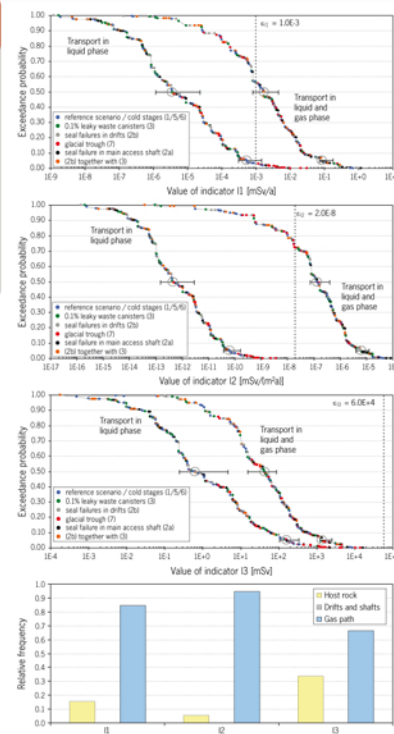
- Significantly higher when both liquid and gas transport paths are considered
- While I2 remains below the insignificance criterion for the solute transport paths, its mean and 95 percentile exceed the criterion for the complete analysis

Indicator I3:

- Median and 95 percentile are below the insignificance criterion in a statistically robust sense

Importance of transport paths:

- The gas transport path determines the indicator values for most of the realizations



8 Conclusions

Two-phase flow and tracer transport:

- The dominant solute transport path is through the host rock
- For the release of ¹⁴C in the gas phase, only the path along drifts and shafts is potentially relevant

Radionuclide transport:

- ¹⁴C release through the gas phase dominates indicator I1 and especially indicator I2 by far. Because of the rather short half life of ¹⁴C as compared to the total assessment time period its influence on indicator I3 is smaller
- The transport of dissolved radionuclides along drifts and shafts has no statistically relevant impact on the indicators

Statistical analysis:

- Due to the high contribution of gaseous ¹⁴C, the median values of indicators I1 and I2 are above the criterion of insignificance
- The 95 percentile of indicator I3 is below the insignificance criterion

Consequences:

- The release of ¹⁴C in the gas phase along drifts and shafts is an important issue for the safety assessment for nuclear repositories in clay. Further investigations should concentrate on the relevant processes related to ¹⁴C, e.g., stoichiometry and kinetics of its mobilization, transport processes and barriers beyond the isolating rock zone as well as the particular biosphere pathways

The probabilistic long-term safety assessment based on performance indicators is currently being used to compare this generic repository in clay to a potential repository in salt rock.

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References: Project VerSi – Vergleichende Sicherheitsanalysen, Comparing Safety Assessments, <http://www.bfs.de/en/endlager/Standortfindung.html/versi.html>
VPAC – A numerical model for groundwater flow and radionuclide transport, Nagra Project Report NAB 08-05, Nagra, Switzerland