Introduction
In the framework of the Belgian research program on the long term management of high-level and/or long-lived radioactive waste, coordinated by ONDRAF/NIRAS, the Boom Clay is considered as a potential host rock for the geological disposal of high-level and/or long-lived radioactive waste in NE-Belgium (Campine area). In the framework of the performance assessments of a disposal system located in the Boom Clay formation, the transport of radionuclides diffusing through the clay barrier into the aquifer located above is modelled. The transport model for this Neogene aquifer is based on the Local model used for the groundwater flow simulation. This Local model has an area of approximately 65 km² and was originally built for the low-level surface disposal radiological safety and impact assessment for the geosphere (Gedeon et al., 2011). This Local model was updated in 2010, following the 2008 site characterization campaign (Beerten et al., 2010), which included extensive CPT (cone penetration test) prospection leading to a better characterization of the Neogene aquifer main aquifard (Kasterlee Clay), and re-definition of the site’s hydrostratigraphy, as well as numerous lab and pumping tests to quantify hydraulic conductivity, porosity, density, etc.

Model setup
A constant radionuclide source flux is defined at the bottom of the model, coincident with the top of the Boom Clay. A square source of 1 x 1 km is assumed, corresponding to a hypothetical repository footprint at the reference site in Mol. The radionuclide decay is neglected, since only long-lived radionuclides are expected to leach out of the Boom Clay. Both, advection-dispersion and diffusion processes are included in the model. The latter process is required to simulate the transport in the lowest parts of the Neogene aquifer system (Berchem and Voort Formations), where the combination of the low hydraulic gradient associated with the catchment divide and a relatively low hydraulic conductivity result in very low groundwater velocities and correspondingly low Peclet numbers.

The value of the coefficient of molecular diffusion of 5.42 m²/d (6.27 x 10⁻⁹ m²/s) was chosen, as interpreted as aarteten (2005) from pulse injection experiments on Mol 3 (Vemaere et al., 2002) borehole cores. To account for the existing uncertainty in the measured hydraulic conductivity values (Figure 3 – bars), the model parameterizations developed by Rogiers et al. (2012) were used (Figure 3 – lines), whereby the ten calibration cases feature a rather large range of hydraulic conductivity for the Diest (41 – 56 m/d), Dessel (0.4 – 5.6 m/d) and Berchem/Voort (0.012 – 0.02 m/d). These ten cases use alternative Kasterlee Clay hydraulic conductivity fields constructed by conditional statistical simulations based on the CPT data (Figure 4).

RESULTS
Generally, the radionuclides are expected to remain close to the top of the Boom Clay until arriving close to the regional sink – Kleine Nete River – where they are carried upwards. All modelled concentration distributions indeed follow these expected particle paths and stretch between the source and the sink.

The total mass at the steady-state, the time of achieving a steady-state and the steady-state concentrations above the source (in the Voort Sands) are however very different, and compared with the key hydraulic conductivity parameter for the 10 model parameterizations. The simulation cases 1-5 have a long steady-state time (>60 ky) and feature a large steady-state mass (>3 x 10¹⁴ Bq) with high steady-state concentrations in the Berchem/Voort Sands. This is correlated with the relatively low values of the hydraulic conductivity of Diest, Berchem/Voort and the Kasterlee Clay.

On the other hand, cases 6,7,8 and 10, featuring large hydraulic conductivities reach the steady-state faster (<30 ky) and have significantly lower total contaminant mass (<2 x 10¹³ Bq) and Berchem/Voort concentrations. Case 9, despite featuring low hydraulic conductivities reaches steady state much faster than cases 1-5 and the total contaminant mass is almost the same as the in cases 6,7,8 and 10. The reason for this behaviour is probably the spatial variability in the Kasterlee Clay hydraulic conductivity (Figure 4). The concentrations in Berchem/Voort are relatively high (although not as high as in cases 1-5), 10, owing to low values in the Berchem/Voort and the Diest Sands.

Conclusion
A series of transport simulations were performed for a series of flow model parameterizations featuring a rather large range of hydraulic conductivity for the different Neogene aquifer units at the Mol site. The simulated concentrations depend largely on the hydraulic conductivity used in the flow model, and therefore, quite different results are obtained. The uncertainty in the measured values of the Berchem/Voort hydraulic conductivity translates into significant differences in the predicted maximum concentrations in the Diest Sands.

Since the previous site characterizations focused on the shallow parts of the Neogene aquifer, considerable uncertainty remains concerning the hydraulic conductivity of the lower aquifer units. As the ranges found by inverse optimization of different Kasterlee Clay concepts are still very large, new regional characterization of the lower aquifer units would be required to properly condition the model.

Nevertheless, many of the different concepts give comparable results, which allows to divide the outcomes into three categories: 1) fast steady-state and low total contaminant mass, 2) slow steady-state and high total contaminant mass, and a less likely 3) fast steady-state and high contaminant mass.

References

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