GROUNDWATER AGE AND LIFETIME EXPECTANCY MODELLING APPROACH FOR SITE CHARACTERIZATION AND PERFORMANCE ASSESSMENT OF RADWASTE REPOSITORY IN CLAY FORMATION

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A deep geological repository of high level and long lived radwaste requires an understanding of the far field and near field groundwater flow and of the transport properties, at actual and future climatic conditions. Andra, French National radioactive waste management Agency, is developing since last 15 years an integrated multi-scale hydrogeological model of whole Paris basin of 200000 km^2 of area (regional scale) to produce a regional flow field associated to groundwater behavior. It includes locally the Meuse/Haute Marne clay site of about 250 km^2 of area in the eastern part of the Paris basin that was chosen for the emplacement of a repository. The Callovo-Oxfordian host formation is a clay layer characterized by a very low permeability of the order 10^{-14} m/s, a mean thickness of 130 m at about 500 m depth, and is embedded by calcareous aquifer formations (Dogger and Oxfordian). The hydrogeological conceptual model is based on stratigraphic and petrophysic modeling of the Paris basin and is accounting for the structural, geological, hydrogeological and geochemical data in an integrated way. This model represents 27 hydrogeological units at the scale of the Paris Basin, and it is refined at the scale of the sector to represent 27 different layers that range in age from the Trias to the Portlandien (Andra 2009).

The finite element flow and transport simulator Ground Water (GW) is used to solve for groundwater flow at steady-state in a 3 Million elements model, considering current climatic conditions. The model is calibrated against about 1250 hydraulic head measurements, and results in maximum absolute hydraulic head differences of 20 meters at the regional scale and 3 meters at the local scale (GEOS-CHYN, 2009). The calibrated reference model includes transmissive major faults as well as structures acting as barrier to flow. Groundwater age (the time elapsed since recharge) and lifetime expectancy (the time remaining prior to exit) are variables that are combined and used to assess the repository performance regarding its emplacement in the transposition zone. Age and lifetime expectancy distributions are solved considering advection and dispersion/diffusion processes according to the approach proposed by Cornaton and Perrochet (2006). Advective-dispersive age solutions are compared to available age dates of pore water within the two main calcareous aquifers (Dogger and Oxfordian) that embed the Callovo-Oxfordian host formation. Such a comparison is helpful for the consolidation of the flow calibration, the estimation of the transport porosity field (since porosity is age generator) and for analyzing the internal water mixing processes and hydraulic behavior of major faults. Lifetime expectancy solutions are used to predict the response at the biosphere resulting from contaminant mass input occurring at a series of hypothetical repository locations. Lifetime expectancy solutions combined with age solutions provide the distribution of total residence times within the domain (i.e the total time required to travel from recharge to discharge). The latter is used to map in the 3-D space the low- and high-speed flow zones at the local scale.

Finally, the behavior of age solutions is investigated when the hydraulic regime is rendered transient in response to the climatic evolution during the past Million years and to the climatic projection for the coming Million years. Transient age solutions at actual time are useful to analyze the effect of the temporal flow regime variations on the measured age dates and on ages simulated under steady-flow conditions.

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