C07

Simulation of Gas Migration in a Waste Disposal in Deep Clay Formation - What Pathways? What Time and Space Scales?

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SUMMARY

A radioactive waste disposal in a deep clay formation is mainly based on the low, water and gas, permeability of the host rock. This property returns to a low capacity of gases evacuation and hydrogen produced by anoxic corrosion and radiolysis of organic waste, will affect the repository on time.
At first raises the phenomenological question at the different space scales: what processes? , what pathways? , what gas pressure? , what couplings?
Secondly raises the question of the safety functions: opening of preferential pathways due to gas fracturation?, transfer induced by water displacement due to gas or transfer in gas form?
A first answer was brought by Andra in the Dossier 2005-Argile which concluded on the feasibility of the disposal.
Since then, Andra has continued (i) researches on characterization of gas migration processes, and (ii) numerical simulation of the production and the migration of gas. The numerical work is covering scales from the disposal cell up to the whole disposal and from operating period to long term post closure. These new results will in term contribute to update a pluriannual program of data acquisitions on fundamental mechanisms of gas production and migration.

A high level and long live radioactive waste geological disposal in a deep stiff clay formation, like Callovo-Oxfordian in the East of the Paris Basin, is mainly based on the low water permeability of this clay host rock. This property also intrinsically returns to a low capacity of gases evacuation. However production of gases, mainly hydrogen by anoxic corrosion of ferrous materials (reduction of water) and radiolysis of organic waste, will affect the repository on time.

At first raises the question of hydrogen migration on time at different space scales of the disposal: what processes (two phase flow, diffusion in dissolved form, others)? , what pathways for transfer (host rock, disposal)? , what form? , what gas pressure? , what gas flows? , what couplings between gas production and migration and other processes, in particular mechanics? Secondly we have to deal with the effects on the safety functions of the disposal system: for example fracturing of the argillaceous host rock that could lead to preferential pathways for radionuclide, porous water displacement in host rock and/or disposal facilities during gas transient period, transfer of radionuclide induced by water displacement due to gas or in gas form.

A first series of answers was brought by Andra within the framework of the Dossier 2005-Argile which concluded on the feasibility of the disposal, in particular: a maximum gas pressure (several MPa) within the repository lower than the fracturing pressure of clay host rock, significant migration pathway for gaseous phases through all the disposal facilities (galleries, shaft, ramp), and preferential evacuation of gas in dissolved form by diffusion in the clay host rock on long term (a few tens to hundreds of thousands of years).

In view of a licensing application for the authorization to create a disposal in 2015, and to answer the recommendations of the Dossier 2005-Argile reviewers, Andra has continued (i) researches on characterization of gas migration processes in deep stiff clay formations and engineered materials of the disposal (concrete, bentonite…), and (ii) numerical simulation of the production and the migration of gas within the clay host rock and the disposal facilities by gradually integrating the scientific knowledge acquired in particular in underground research laboratories. This work is illustrated for various examples of simulation using Tough tools, from the scale of the disposal cell up to the scale of the whole disposal and the surrounding clay host rock, covering operating period and post closure period (during at least several tens of thousands of years). Special effort was made to treat operating period according to both safety of workers and phenomenological states for retrievability.

The figure 1 highlights a 2D simulation of the coupling between water inflows from clay host rock, gas production by anoxic corrosion of metallic ILL radwaste, water consumption by corrosion, taking into account the various voids within the disposal cell. It shows vertical separation of gas and liquid water in waste packages and voids and real impact of the water saturation state in the different waste packages.

The current results stress five particular points:

1 - The potential importance of the interfaces between engineered materials and between these materials and the clay rock on the migration of occurring gases, in particular at seals (disposal cells, galleries, access shafts/ramp); These interfaces may offer preferential pathways for gas migration from waste disposal cell to access galleries then access shaft and ramp, in comparison to EDZ
2 - The probable weak penetration as truly gaseous phases into the clay rock due to high capillary curve ; gas pressure of several tens of MPa are needed to give significant unsaturated state of undisturbed deep clay
3 - The relative roles of exchange surfaces offered by the disposal facilities on one hand to the clay rock and on other hand to the geological formations surrounding the clay formation through the access of the disposal, with respect to the gas pathways;

disposal facilities offer exchange surface with host rock of several millions of square meter in comparison with several ten square meter for exchange surface of access. This ratio may be not compensated by ratio of gas permeabilities of undisturbed clay host rock and of swelling clay based seals of access and/or interfaces

4 - The relative couplings between production of hydrogen and water consumption by anoxic corrosion; in conjunction with the limitation of water inflow by clay host rock due to its low water permeability. This coupling seems to depend mainly on corrosion rate (i.e. type of metallic component) and on surfaces offered by metallic component for corrosion.

5 - The competition between transfers of gas in dissolved form by diffusion and in truly gaseous phase by advection, into the clay host rock.

These results contribute to define a pluriannual program of data acquisitions on fundamental mechanisms of gas production and migration, and of in situ experiments at scales representative of a disposal in terms of validation. In parallel research on chemical behavior of dissolved hydrogen in clay host rock are going on according to the flow of dissolved hydrogen within the porosity of the clay at large scale in time.

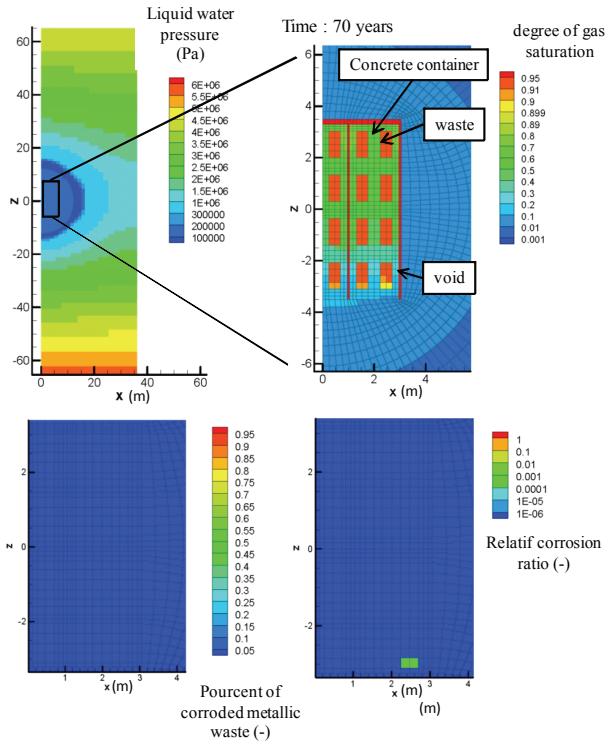

Figure 1 *Degree of gas saturation within an ILLW disposal cell at 70 years after closure (use of Though2).*