Hydrogeological baselines for geothermal energy and heat storage in old flooded coal mines in urban areas

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Abandoned mines can play a new role in renewable energy production and storage in combination with fifth generation heating and cooling networks. Obviously, the underground potential must be matched with the uses/productions of heat and cold by surface activities. Therefore, this will be considered here only in highly urbanized areas or in economic and industrial areas.

Flooded abandoned mines form highly heterogeneous aquifers that are artificially and locally highly permeable around former underground works (i.e., tunnels, galleries, mined extraction zones, wells, shafts). Thermal energy storage (ATES) systems, using heat-pumps and an open loop with a groundwater pumping and re-injection doublet, are thus challenging and uncertain in such a variable underground environment. Hot water is pumped in the deepest parts of the open network, and cold water can be re-injected in the shallower parts (i.e. in shallower galleries or fractured rocks). A seasonal inversion could be planned for cooling the buildings during the summer season. However, the true geometry of the interconnected network made of old open galleries and shafts can be highly complex and partially unknown. Indeed, high-velocity water flow and heat transport are expected in this network inducing potentially a full or partial bypass of the fractured and porous rock massif.

A hydrogeological characterization of the old mined zones for detailed simulations of the groundwater flow and associated heat transport is thus a needed step allowing to assess the actual feasibility of a given project. The simulated short-, mid- and long-term temperature evolution in pumping and injection zones will consist in key information for designing and dimensioning the whole geothermal project and assessing future efficiency and impact. Depending on the degree of precision required, that is dependent on the level of reduction of uncertainties associated with the geothermal project, the hydrogeological baseline issues can be very significant, challenging scientists in different areas of quantitative hydrogeology:

1) conceptualization in a simple model of the often unknown complexity/heterogeneity of the galleries network conjugated to those of the mined geological formations;
2) simulation of temperature dependent variable density groundwater flow and coupled heat transport;
3) combining high-velocity 'pipe-like' water flows (in the shafts and galleries) and porous/fractured groundwater flow (in the rock matrix);
4) simulation of different transient scenarios to assess evolutions in the long-term.

As an illustration, a simplified but realistic situation is simulated showing the influence of the highly different heat/cold transport in the galleries and shafts, compared to the propagation in the porous/fractured rocks. Indeed, the different temperature evolutions allow to anticipate the temperature changes affecting the future (short-, mid-, and long-term) efficiency of a geothermal system as well as possible environmental impacts.

Real cases in relation with future projects should ideally be simulated using the most detailed approaches, with true data. Those baseline hydrogeological data are not easy to obtain but they are the guarantee of reliable predictions and therefore that the financial risk is reasonable.

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