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Shallow open-loop geothermal systems: simulation of heat transport in groundwater and experimental tests for improving parameterization

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Innovative and efficient strategies for energy utilization become a priority, especially in the civil engineering sector. Geothermal open-loop systems (geothermal wells) are not so developed in Belgium contrary to close-loop systems. This is generally due to the lack of relevant dimensioning and impact study that must be foreseen during the planning phases of the building. However, as shallow groundwater is widely available, geothermal wells potential is significant. Using both experimental and numerical tools, our aim is to develop a rigorous methodology to design heating and cooling shallow geothermal wells (pumping/reinjection), with a detailed hydrogeological characterization, coupled to feasibility, environmental impact assessment, dimensioning and system sustainability.

Groundwater flow and heat transport is computed using different numerical codes (HydroGeoSphere, MT3DMS and SHEMAT) for a comparative sensitivity analysis on a typical case. Coupling and temperature non linearities of the hydro-thermal parameters values are checked accurately. As shown previously, small temperature variations, allow to use conventional solute transport codes modeling heat transport in groundwater taking benefits of the similarities between solute and heat transport equations.

When numerical codes are used as dimensioning tools for long-term simulations, reliable values for hydro-thermal properties of the aquifer are essential. Very few experimental values are available in the literature. Field experiments are needed to determine more accurately the local values in different geological/hydrogeological conditions. Apart from thermal response tests (TRT) usually performed for designing a close-loop system within a borehole considered in static groundwater conditions, there is no standard procedure for geothermal wells systems. In an open groundwater system, groundwater movement induced by the pumping (convection) is a major heat transport process and cannot be neglected. A pilote site is currently studied for optimizing methods in such low temperature geothermal systems. The field experiments include: pumping tests (for hydraulic conductivities to be used for dimensioning tracer and heat tracing tests), solute tracer tests, heat tracing tests. Hot water injection, is combined with downstream pumping and intermediate temperature and pressure monitoring piezometers for detection of the heat plume shape. Natural temperature variations, due to air temperature day/night and interseasonal cycles and also induced by the river proximity, are filtered.

The test characteristics and first results are detailed showing that the combined use of solute tracer tests and heat tracing tests leads to a better characterization of the local hydro-thermal properties.

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