Development of a Thermo-Hydro-Geochemical Model for Low-Temperature Geoexchange Applications

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Abstract

Standing column wells (SCW) are open-loop geoexchange systems used to provide space heating and cooling to buildings. As they use groundwater as heat carrier fluid and modify its thermo-chemical conditions along the year, they may favor calcite dissolution and precipitation, thus increasing maintenance costs. In order to predict the thermo-hydro-chemical (THC) processes occurring in a SCW and its surrounding geological environment, a 2D axisymmetric coupled multiphysics model was developed in COMSOL Multiphysics® software (Figure 1).

The model uses three different physics from the Subsurface Flow Module (Darcy's Law, Heat Transfer in Porous Media, and Solute Transport), and the ODE and DAE nodes to link species transport and temperature dependent reactions. A mixed kinetic-equilibrium formulation is used to simulate geochemical reactions involving nine aqueous species. Precipitation and dissolution are modeled as slow reactions while local equilibrium reactions are expressed as fast reactions. To reduce the number of transport equations from nine to three, the activities of the species are grouped in three equations according to the Tableaux Method. The reaction rate of calcite is expressed by the PWP model based on three elementary reactions which are integrated in a reaction term in the Solute Transport interface. The rate constants and the equilibrium constants take into account the groundwater temperature, thus allowing coupling the temperature and the chemical reactions.

The results demonstrate that calcite dissolution and precipitation occur in the well and the surrounding environment during a typical 1-year operation involving heating and cooling (Figure 2 and 3). Thus, the presented numerical tool evidences the need for water treatment systems to provide SCW operation scheme.

Reference

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Figures used in the abstract

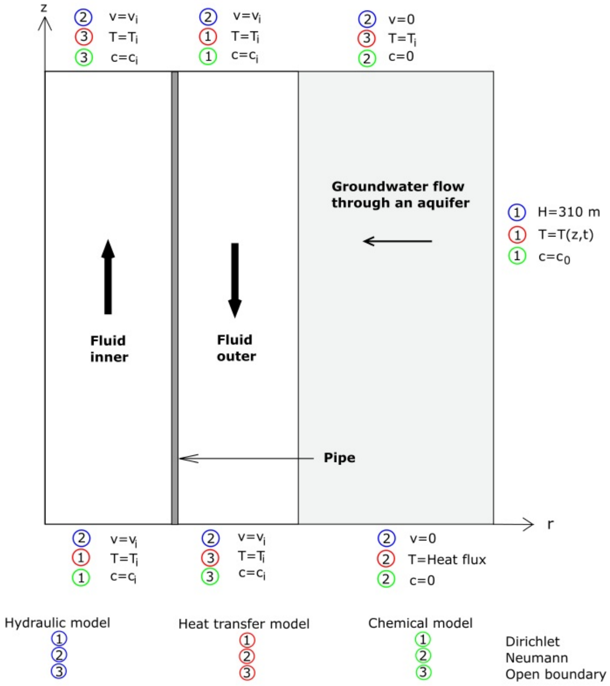

Figure 1: Simplified representation of a standing column well (SCW) and boundary conditions of the developped model. Adapted from Nguyen et. al. (2015).

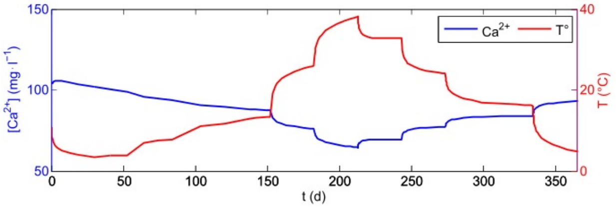

Figure 2: Evolution of the temperature and the concentration of Ca2+ evaluated at the base of the well during a typical 1-year operation involving heating and cooling.

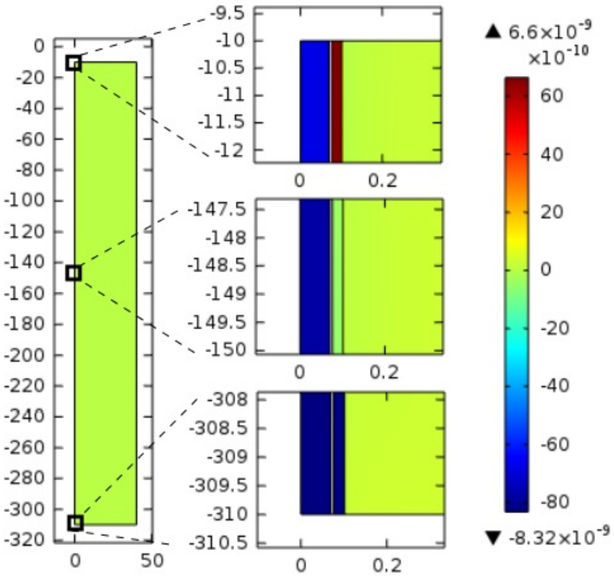

Figure 3: Reaction rate of calcite (mg·cm-2·s-1) in the well and the surrounding environment at the end of January (in heating mode). When the rate is positive, dissolution occurs in the system and when the rate is negative precipitation takes place.

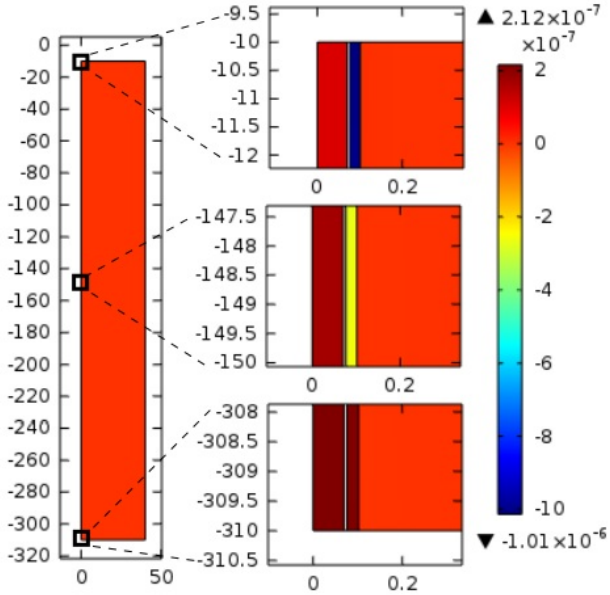

Figure 4: Reaction rate of calcite (mg·cm-2·s-1) in the well and the surrounding environment at the end of July (in cooling mode). When the rate is positive, dissolution occurs in the system and when the rate is negative precipitation takes place.