Laboratory experiments on thermal retardation and local-thermal-non-equilibrium effects on heat transport in conditions of a highly conductive aquifer

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Abstract

Near surface geothermal energy systems play a significant role in the aim of increasing the share of renewable energy. However, to ensure the economically and environmentally sustainable usage of the geothermal systems, information about heat transport parameters (thermal and hydrodynamic parameters) is crucial for forecasting the thermal transport in the aquifer and the storage behavior of the subsurface. Furthermore, the prediction of thermally affected zones in the subsurface is a key parameter in the impact assessment of these systems. Thermal and hydrodynamic parameters, i.e. heat capacity and mean groundwater velocity, can be determined by the use of the thermal retardation factor. The Munich Gravel Plain is a highly conductive aquifer which is intensively used for geothermal heating and cooling. Its geothermal potential is investigated in the GePo and GeoPot project. The aim of this study is to evaluate the applicability of the thermal retardation factor for determining hydrodynamic and thermal parameters in highly conductive aquifers. Furthermore, we would like to explore the validity of the local-thermal-equilibrium (LTE) approach and the influence of local-thermal-non-equilibrium (LTNE) effects on thermal retardation in conditions of a highly conductive aquifer.

Laboratory experiments are conducted to evaluate under which flow velocities the use of the thermal retardation factor for determining thermal and hydrodynamic aquifer parameters in highly conductive aquifers is valid. The effect of LTNE on thermal dispersion and thermal retardation is investigated. In a series of column experiments filled with gravels the development of the temperature (fluid and solid) under different flow conditions is studied. Gravel is used to simulate the conditions of a highly conductive aquifer. Hydrodynamic flow conditions such as dispersion and water flow velocities are characterized by additional solute tracer tests.

First results show that the thermal peak velocity may significantly differ from the thermal peak velocity predicted by the thermal retardation factor in groundwater systems that show flow velocities of up to around 9 m/d. These first results also indicate that at higher flow velocities advective heat transport is dominant over thermal dispersion and the thermal retardation factor can be used to determine the involved quantities like flow velocity and heat capacity. Furthermore, at low flow velocities thermal breakthrough time can be overestimated if the thermal retardation factor is used in thermal impact assessment.