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Investigation of the influence of groundwater advection on energy extraction rates for sustainable borehole heat exchanger operation

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A sustainable thermal exploitation of the shallow subsurface requires a precise understanding of all relevant heat transport processes. Currently, planning practice of shallow geothermal systems (especially for systems < 30 kW) focuses on conductive heat transport as the main energy source while the impact of groundwater flow as the driver for advective heat transport is neglected or strongly simplified. The presented study proves that those simplifications of complex geological and hydrogeological subsurface characteristics are insufficient for a precise evaluation of site-specific energy extraction rates. Based on synthetic model scenarios with varying subsurface conditions (groundwater flow velocity and aquifer thickness) the impact of advection on induced long term temperature changes in 5 and 10 m distance of the borehole heat exchanger is presented. Extending known investigations, this study enhances the evaluation of shallow geothermal energy extraction rates by considering conductive and advective heat transport under varying aquifer thicknesses. Further, it evaluates the impact of advection on installation lengths of the borehole heat exchanger to optimize the initial financial investment. Finally, an evaluation approach is presented that classifies relevant heat transport processes according to their Péclet number to enable a first quantitative assessment of the subsurface energy regime and recommend further investigation and planning procedures.