How heterogeneity of the K-field influences a heat plume in a shallow alluvial aquifer: responses from a heat tracer test

Maria KLEPIKOVA[1,2], Pierre JAMIN[1], Philippe ORBAN[1], Serge BROUYERE[1], Alain DASSARGUES[1,*]

[1] University of Liege, ArGEnCo, GEO³, Hydrogeology and Environmental Geology, Aquapôle, B52/3 Sart-Tilman, 4000 Liege, Belgium
[2] now at ETH Zurich, Geological Institute, Zurich, Switzerland
*Corresponding author: Alain.Dassargues@ulg.ac.be, +3243662376

Keywords: shallow geothermal system, heat tracer test, inverse modelling, pilot points,

Abstract
Simultaneous solute and heat tracer test provides essential information for a reliable assessment of low temperature geothermal systems. The actual efficiency of 'open systems', including heat storage projects, is strongly affected by the heterogeneity of the hydraulic conductivity field (*K*-field). It could be also useful for assessing the cumulative impacts of numerous projects in urban areas on the groundwater resources.
Using field data from a solute and heat tracer test conducted in the alluvial aquifer of the Meuse River (Belgium), an inverse problem of parameter estimation is solved. The tracing experiment consisted in simultaneously injecting heated water and a dye tracer in a piezometer and monitoring the evolution of groundwater temperature and tracer concentration in the recovery well and in monitoring wells. To get insights in the 3D characteristics of the heat plume, an arrangement of three transects of observation wells was used.
The breakthrough curves measured in the recovery well showed that heat transfer in the alluvial aquifer is slower and more dispersive than solute transport. Recovery is very low for heat while in the same time it is measured as relatively high for the solute tracer. This is due to the fact that heat transport is a thermal diffusion dominated process. For conditions corresponding to high Peclet numbers, the hydraulic conductivity is the primary calibration parameter for predicting heat plume distribution. Heat diffusion is larger than molecular diffusion, implying that exchange between groundwater and the porous medium matrix is far more significant for heat than for solute tracers.

Acknowledgments M. Klepikova gratefully acknowledges the financial support from the University of Liège and the EU through the Marie Curie BeIPD-COFUND postdoctoral fellowship programme (2013-2014).

References
- Derouane J. & Dassargues, A., 1998, Delineation of groundwater protection zones based on tracer tests and transport modelling in alluvial sediments, *Environmental Geology*, 36 (1-2), pp. 27-36.
- Dassargues A., Wildemeersch S., Rentier C., 2014, Graviers de la Meuse (alluvions modernes et anciennes) en Wallonie, in *Watervoerende lagen & grondwater in Belgïe – Aquifères & eaux souterraines en Belgique*, Partie 1, Chapitre 4, pp. 37-46. Dassargues A. & Walraevens C. (Eds) Academia Press.
- Dassargues A., Wildemeersch S., 2014, Géothermie de très basse température, in *Watervoerende lagen & grondwater in Belgïe – Aquifères & eaux souterraines en Belgique*, Partie 2, Chapitre 6, pp. 375-381. Dassargues A. & Walraevens C. (Eds) Academia Press.
- Fossoul, F., Orban, P. and Dassargues, A., 2010, Modelling groundwater pumping and coupled heat transport in a alluvial aquifer: tests using different codes and optimisation, in *XVIII International Conference on Computational Methods in Water Resources*, CMWR 2010, J. Carrera (Ed), CIMNE, Barcelona 2010.
- Fossoul, F., Orban, P. & Dassargues, A., 2011, Numerical simulation of heat transfer associated with low enthalpy geothermal pumping in an alluvial aquifer, *Geologica Belgica*, 14(1-2), pp. 45-54.

- Hallet V., Nzali T., Rentier C. and Dassargues A., 2000, Location of protection zones along production galleries : an example of methodology (Proc. of *TraM'2000 Conference on Tracers and Modelling in Hydrogeology*), A. Dassargues Ed., IAHS Publication n° 262, pp. 141-148.
- Hermans T., Wildemeersch S., Jamin P., Orban P., Brouyère S., Dassargues A. and Nguyen F., 2015, Quantitative temperature monitoring of a heat tracing experiment using cross-borehole ERT, *Geothermics*, 53, pp. 14-26.
- Klepikova M.V., Wildemeersch S., Jamin P., Orban Ph., Hermans T., Nguyen F., Brouyère S. and Dassargues A., 2015, Use and utility of combined solute and heat tracer tests for characterizing hydrogeothermal properties of an alluvial aquifer, CBH-BCH, Belgian National IAH Chapter Study Day on Geothermy, Mons, June 5, 2015.
- Rentier C., Brouyère S. and Dassargues A., 1999, Calibration and reliability of an alluvial aquifer model using inverse modelling and sensitivity analysis, ModelCARE'99, Pre-published Proceedings, Eds. Stauffer F., Kinzelbach W. Kovar, K and Hoehn E., vol.1, pp. 343-348.
- Rentier C., Brouyère S. and Dassargues A., 2002, Integrating geophysical and tracer test data for accurate solute transport modelling in heterogeneous porous media, Groundwater Quality: Natural and Enhanced Restoration of Groundwater Pollution (Proc. Of GQ'2001, Sheffield, IAHS Publ. n° 275, pp. 3-10.
- Wildemeersch S., Jamin P., Orban Ph., Hermans T., Klepikova M., Nguyen F., Brouyère S. & Dassargues A., 2014, Coupling heat and chemical tracer experiments for estimating heat transfer parameters in shallow alluvial aquifers, *Journal of Contaminant Hydrology*, 169, pp.90-99.