The double porosity of the chalk and its influence on solute and heat transport

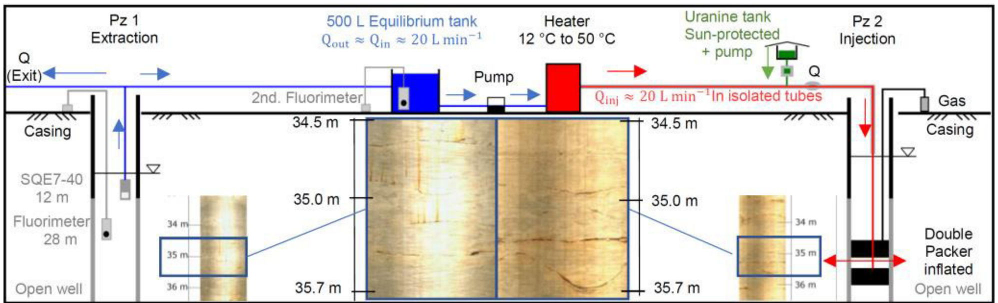
Richard HOFFMANN[1,2], Pascal GODERNIAUX[2], Pierre JAMIN[1] & Alain DASSARGUES[1]
1 Liège University, Urban & Environmental Engineering, GEO³, Hydrogeology & Environmental Geology, Quartier Polytech 1, Allée de la Découverte 9, 4000 Liège.
2 University of Mons, Polytech Mons, Geology and Applied Geology, Rue de Houdain 9, 7000 Mons.

1. Introduction and motivation

Fractured rock aquifers, e.g. Belgium chalk, are important drinking water suppliers where transport processes are influenced by "double porosity effects" (Brouyère et al., 2000; Bodin et al., 2003). These effects cause e.g. a delayed contribution of a liquid or energy from the matrix to the main circulating fluid or vice versa, depending on the direction of the internal gradient (Barenblatt et al., 1960). An advanced characterization and imaging of these "double porosity effects" and "matrix processes" is very useful to quantify their influence on solute and heat transport processes.

2. Test site and experimental set up

A joint heat and solute tracer test was performed between two adjacent 50 m-deep wells Pz1 and Pz2, distant of 7.55 m. The test site called "Pic et Plat" lies in the fractured chalk aquifer of the Mons Basin in Belgium. Based on several first field site investigations (flowmeter tests, optical imaging and hydraulic tests), a horizontal open fracture network with one main fracture was identified at a depth of around 35 m. The main fracture was isolated using an inflatable double packer system installed in Pz2. Hot water (50 °C) was continuously injected at a flow rate of 20 L min-1 within the double packer for 70 hours, while a Grundfos SQE7-40 pumped around 10 m3 h-1 in Pz1 during and after heat injection (Fig. 1). The temperature evolution was measured during 9 days in Pz1 at 28 m deep (i.e., slightly above the expected arrival depth). In parallel, two injections of uranine were performed. One started at the same initial time than the heat injection and the second after 2 days. Both times, 2 g of Uranine were injected with a mass rate of 3.3 mg s-1.



Main data of the used boreholes

	PZ1	PZ2
Diameter [m]	0.15	0.15
Homogenous hydraulic conductivity [m/s]	3.18×10^{-5}	
Estimated transport porosity [-]	0.003	
Estimated dispersivity [m]	0.15	
Injected Temperature [°C]	-	50
Injection time [h]	-	70
Injection rate [$L\ min^{-1}$]	-	20
Observation time of Fluorimeter 28 m deep	9 days	-
Extraction rate [$m^3\ h^{-1}$]	10	-

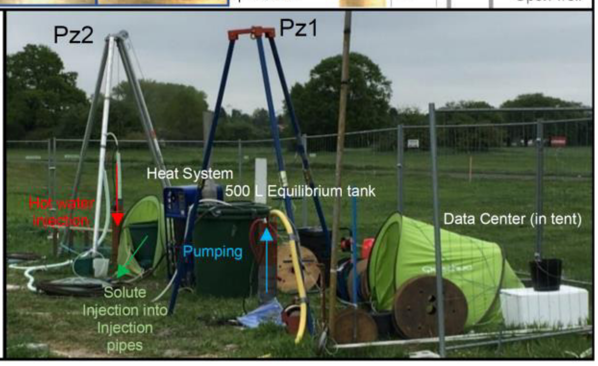


Figure 1: Overview over the test site and the experimental set up.

3. Results

The fluorescent dye tracer (uranine) arrives within around 10 minutes. The heat needs around 12.5 hours to show a first temperature increase of 0.01 °C. The maximum temperature increase observed in Pz1 after 70 hours of heat injection in the Pz2 (located at a distance of 7.55m) is 0.4 °C. After stopping the heat injection, a very direct temperature decrease is visible before slow temperature rebound over several days. On the contrary, the uranine concentrations decrease continuously after the peak (Fig. 2).

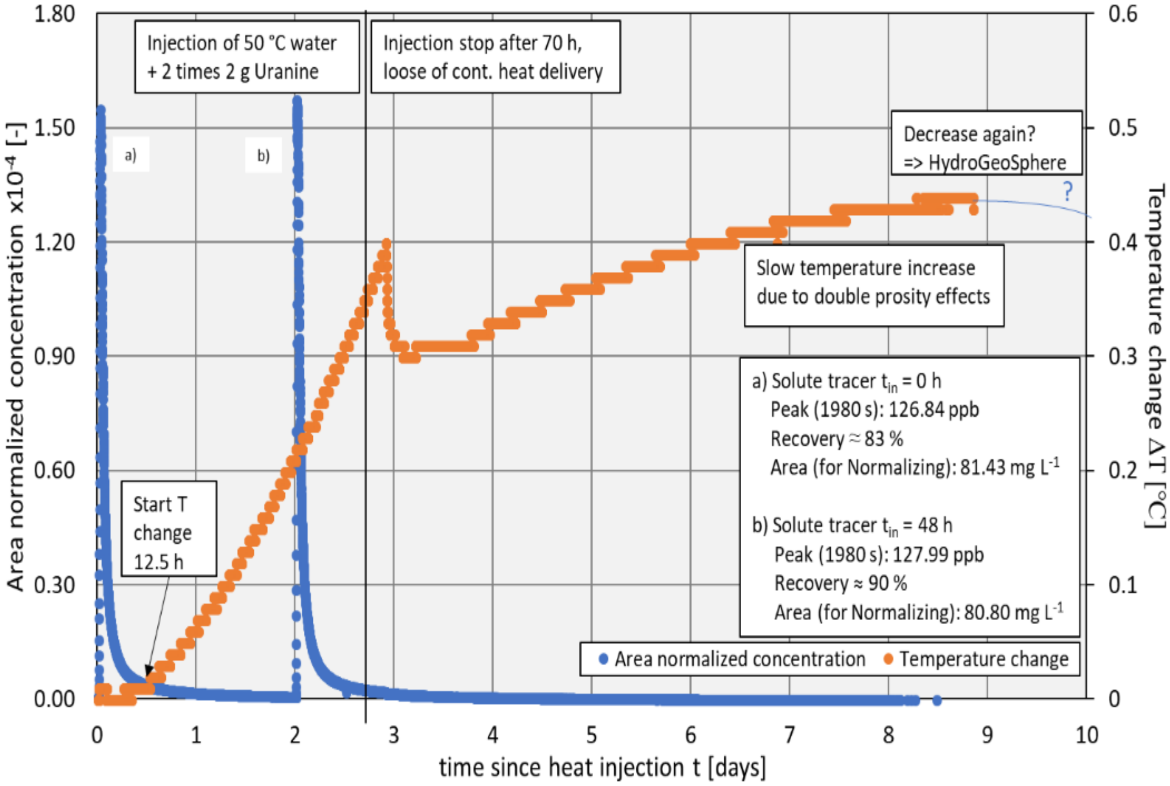


Figure 2. In field observed breakthrough curves of joint heat and solute tracer test in Pz1.

4. Conclusion

The different behaviors between heat and solute transport emphases the effect of the chalk double porosity. In heat transport, the solute diffusion part is replaced by heat conduction, which offers more easily storage in the matrix and causes a strong breakthrough delay. When the injection is stopped, heat shows a rapid decreasing at the recovery well Pz1 due to a loss of continuous heat delivery by the heater beforehand. After this rapid decrease and unlike the solute concentration that continues to decrease to reach initial background values, heat shows a temperature rebound. The matrix reacts here very slowly to thermal diffusion and releases heat back to the colder water drawn from the surroundings by the pumping. For further detailed interpretation, HydroGeoSphere (Therrien et al., 2010) will be used coupling groundwater flow, solute transport and heat transport in this particular double porosity medium.

Acknowledgements

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