Assessing the impacts of chemical and physical heterogeneity on water quality evolution during ASR

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Aquifer storage and recovery (ASR) is an important and increasingly used option for water management in water-scarce regions, during which surplus water is injected into a target aquifer for storage and later recovery. On the other hand, in cases where the aquifer geochemistry is well-characterized and the water quality evolution during injection, storage and recovery is carefully monitored, ASR sites can also serve as important field-scale natural laboratories that allow to study water-sediment interactions under well-controlled conditions.

In this study we use reactive transport modelling (i) as a means to integrate the hydrogeological, geophysical, and hydrogeochemical data that were collected prior and during a 3-year long ASR trial in Perth, Western Australia and (ii) to assess the impacts of aquifer physical and chemical heterogeneities on water quality evolution.

The geochemical processes that were found to mostly affect the water quality evolution include oxidation of pyrite, mineralisation of sedimentary organic carbon, ion exchange, dissolution of calcite and precipitation of ferrihydrite and siderite. Our results ilustrate how different chemical species respond differently to the physical and chemical heterogeneities during the tested ASR cycles: injected species that are stronly impacted by chemical processes (e.g., dissolved O_2 and Ca^{2+}) experience the strongest combined impact of physical and chemical heterogeneities. On the other hand, species which are mostly generated in situ (e.g., SO_4^{2-}) are only weakly affected by a combination of physical and chemical heterogeneity. In the studied case, physical heterogeneity generally determines the spatio-temporal distribution pattern of aqueous species while chemical heterogeneities and the injection water composition constrain the overall geochemical turnover and thus the absolute concentrations of reactive species.