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How can magnetic resonance imaging (MRI) help understanding colloidal particle transport in soils.

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The capability to predict the fate of colloidal particles in the subsoil is of paramount importance for scientists, engineers or policy-makers, as such particles can carry adsorbed pollutant towards the groundwater or be themselves pollutants.

Current models often fail to predict observed colloid fate, indicating the need for a better understanding of the processes controlling colloid attachment, detachment and transport in the soil. Most of these processes can only be studied indirectly (e.g. using particle breakthrough curve (concentration as a function of time) recorded during simulated rainfalls). For this reason, the soil can be considered as a “black box” system.

Imaging techniques (X-ray tomography, MRI) have increasingly been used to open the black box and study water movement in soil cores, but they have seldom been applied to investigate the fate of colloidal particles in soils.

With the aim of gaining internal information on their transport, we injected a pulse of superparamagnetic nanoparticles (longitudinal relaxation $70 \text{ s}^{-1} \text{ mM}^{-1}$) in saturated sand columns and recorded: (i) their effect on proton MRI signal (double spin echo sequence, acquisition duration 70 s) as a function of the core depth (150 mm, resolution 1.6 mm) and time and (ii) the particle breakthrough curves at the column outlet. The nanoparticles were either negatively (np^-) or positively (np^+) charged.

We found that, as expected in negatively charged quartz sand, np^- particles were entirely recovered at the column outlet, while np^+ particles were completely retained. For both particles, MRI recordings permitted to follow particle pulse displacement in the columns, providing otherwise inaccessible information on the retention dynamics and locus of np^+ particles. Interestingly, we found that both suspended and adsorbed nanoparticles had an effect on the measured MRI signal. For this reason, we built two calibrations relationships between the MRI signal of suspended (respectively adsorbed) particles and their concentration in pore water (respectively on the solid phase). We then compared the recorded MRI signal with the signal computed from these calibrations and the outputs of a colloid transport model based on a kinetic reversible particle deposition onto sand grains.

In this contribution we will discuss how the large spatially and time resolved internal data yielded by MRI (i) features this technique as a cutting edge tool to test colloid transport models to their very limits and (ii) provides an unmatched situation to understand ‘why’ and ‘where’ particle retention occurs.

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