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Colloid-induced multi-scale multiphase flow perturbations in porous media

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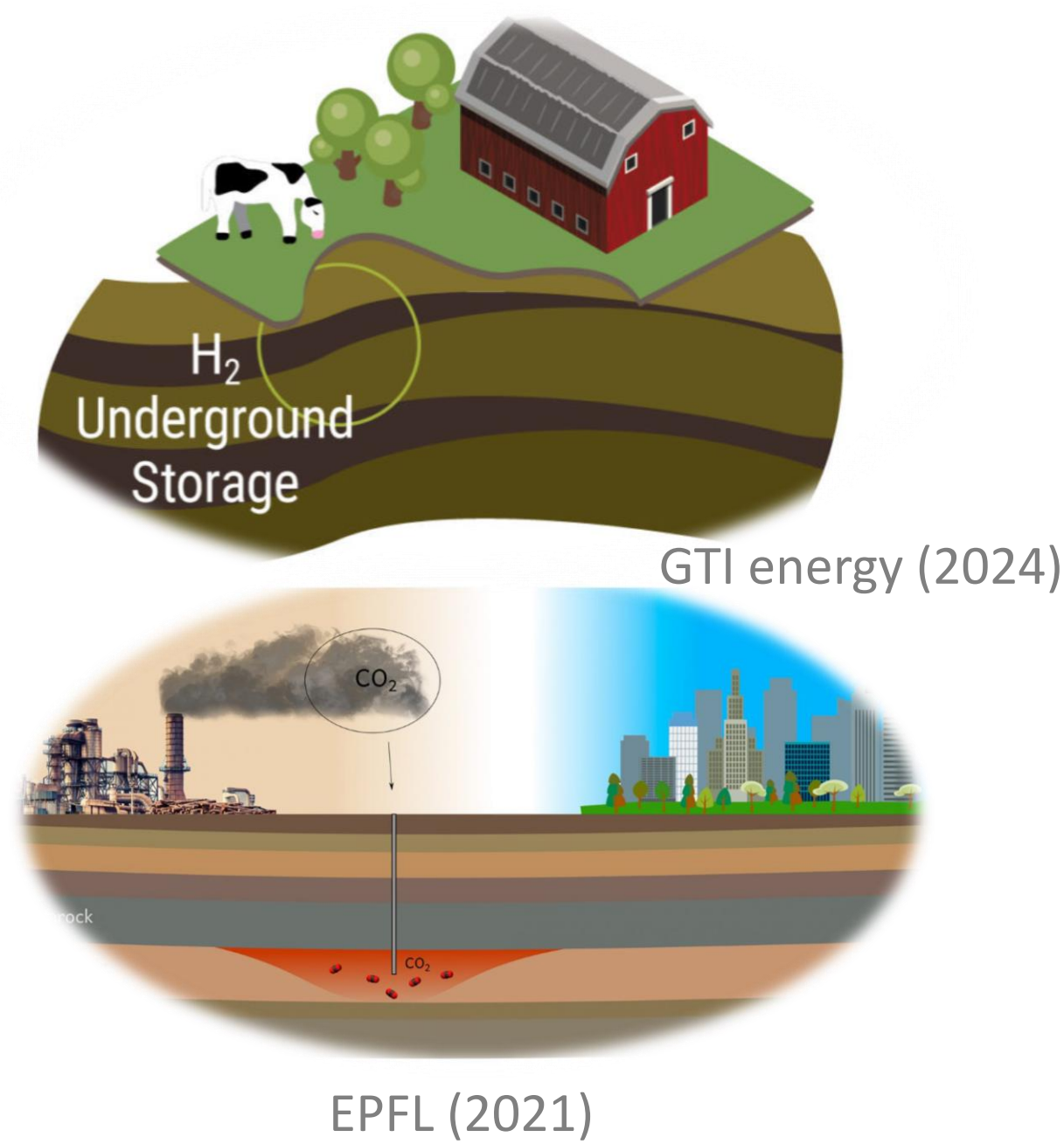
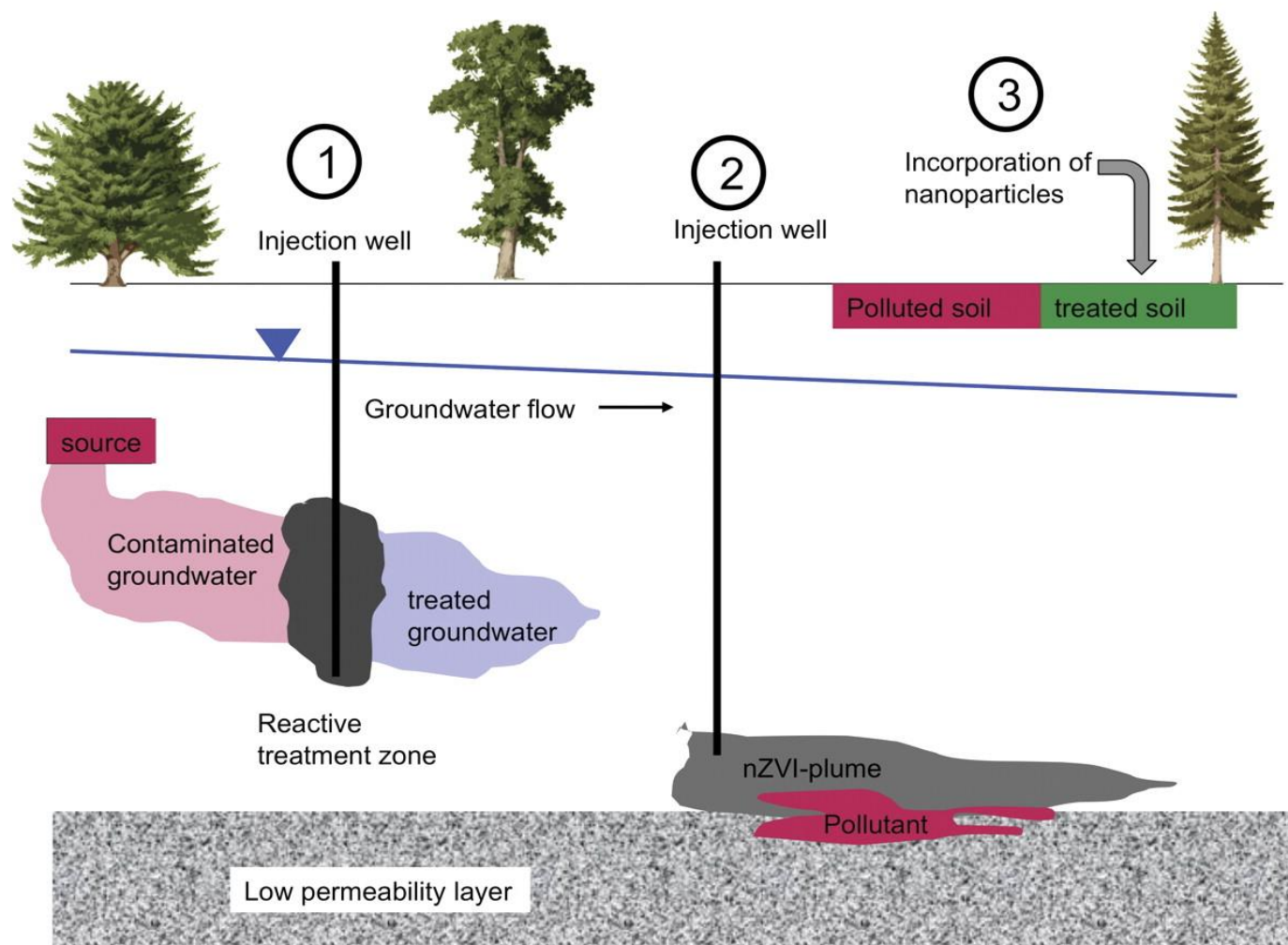
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Motivation

- Fate of colloids in porous media is important for many environmental applications including groundwater remediation.
- These colloids have huge potential to mobilize contaminants such as non-aqueous phase liquids (NAPL) trapped by capillary forces [1].

Groundwater remediation

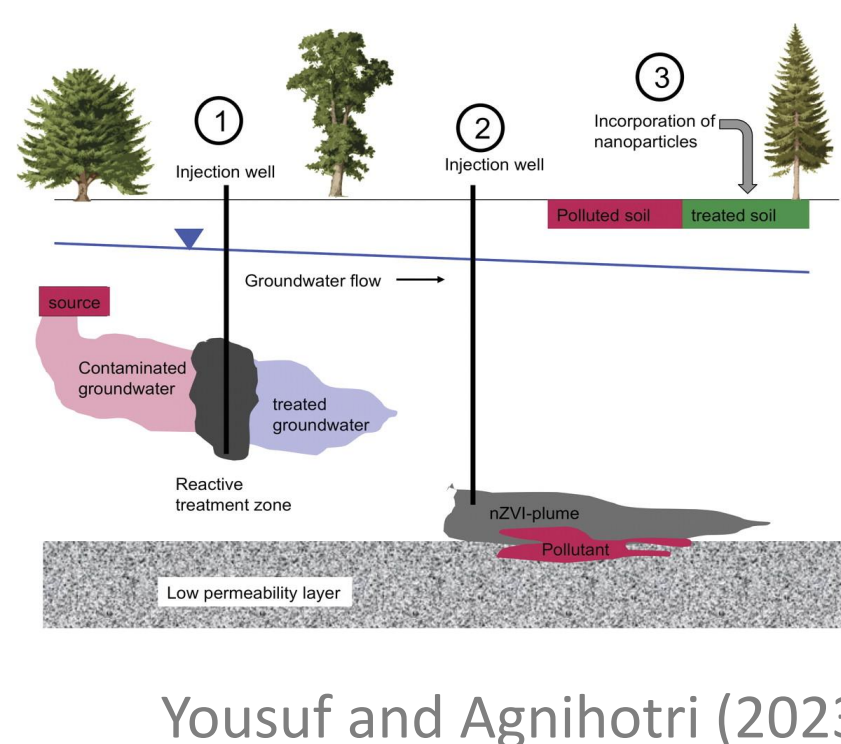


Scientific background

- Colloid transport is influenced by pore geometry, surface interactions, flow conditions, and particle size [2].
- Multi-scale mechanisms driving colloid-induced mobilization of NAPL, from microscopic interfaces to pore networks and field-scale processes, are poorly understood.
- To fill these knowledge gaps, this study aims to investigate the mechanisms behind colloid-induced pore clogging, which modifies flow and mobilizes trapped NAPL in porous media.

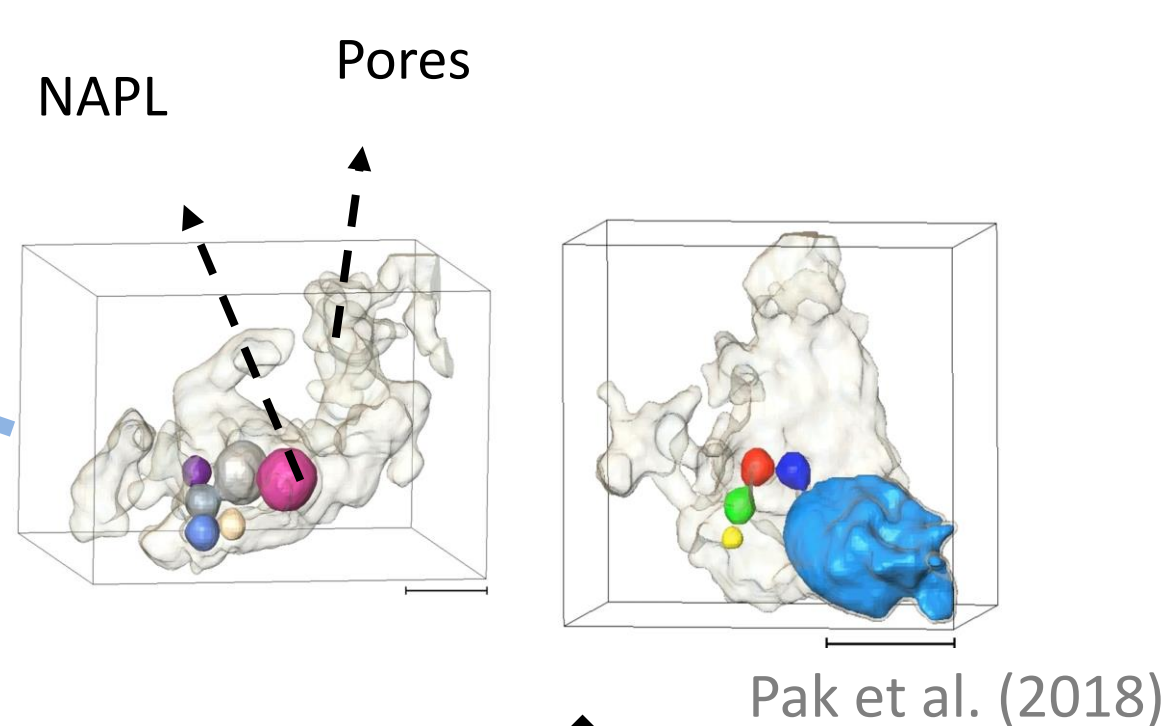
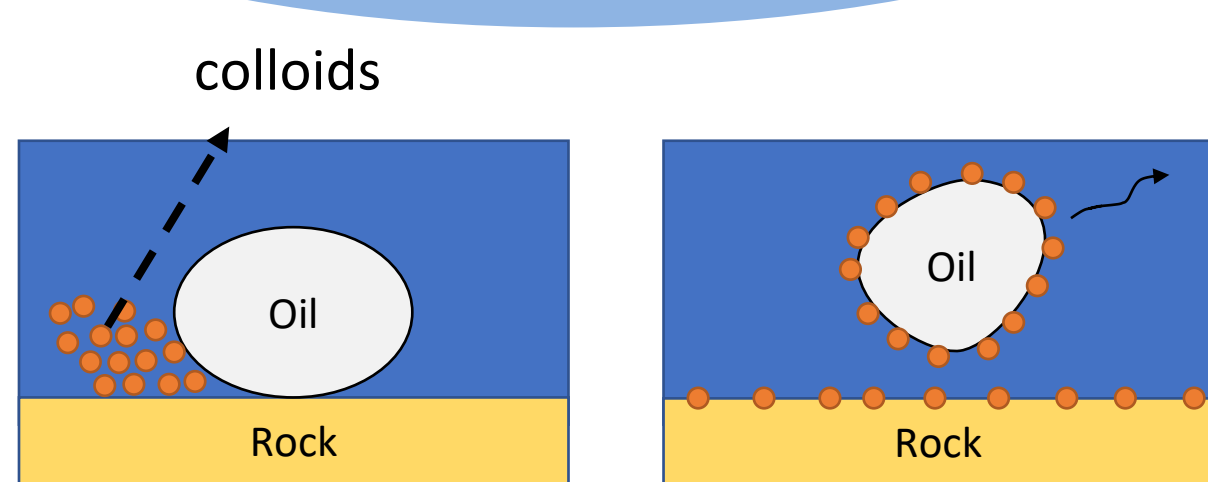
Macroscopic scale

Colloids are carriers of contaminants in porous media at column and field scale [1].



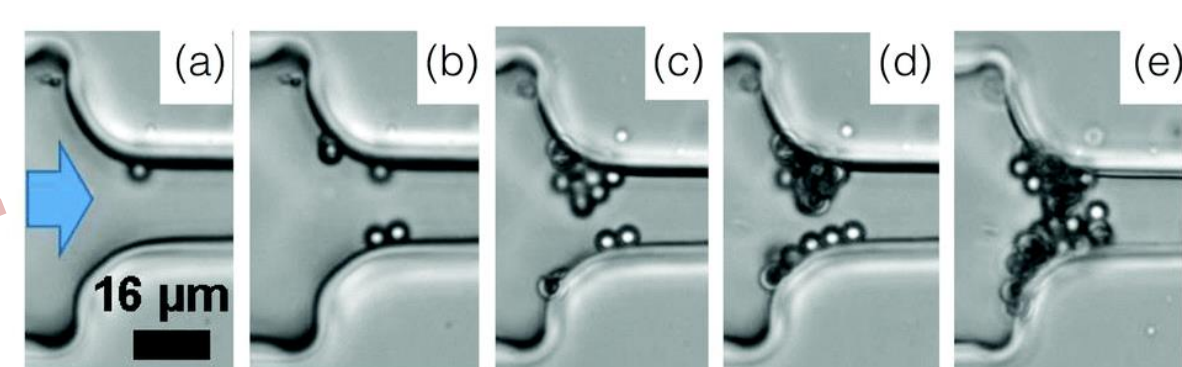
Network of pores

Reduction in interfacial tension and capillary forces eases the remobilization of the trapped NAPL phase [3].



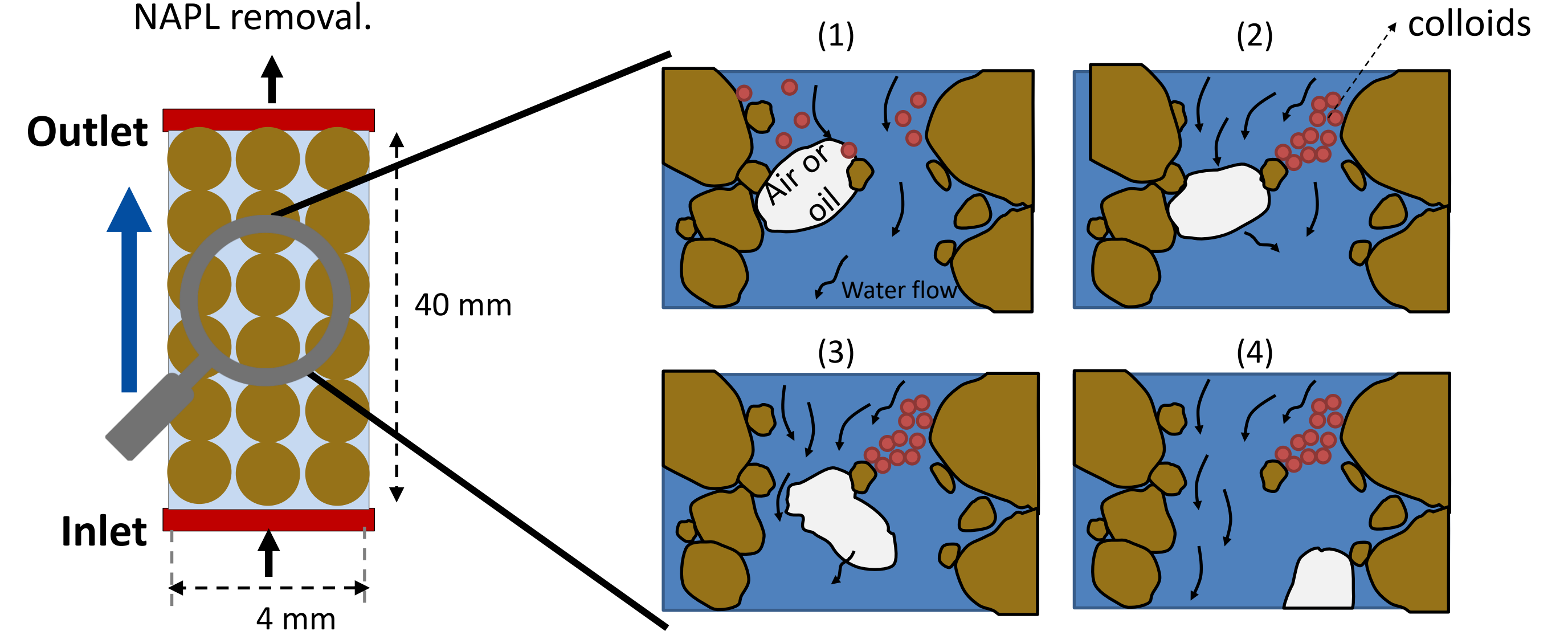
Microscopic interfaces

Evidence of pore clogging and hydrodynamic forces alteration from microfluidic experiments, however, lacking the third dimension [4-5].



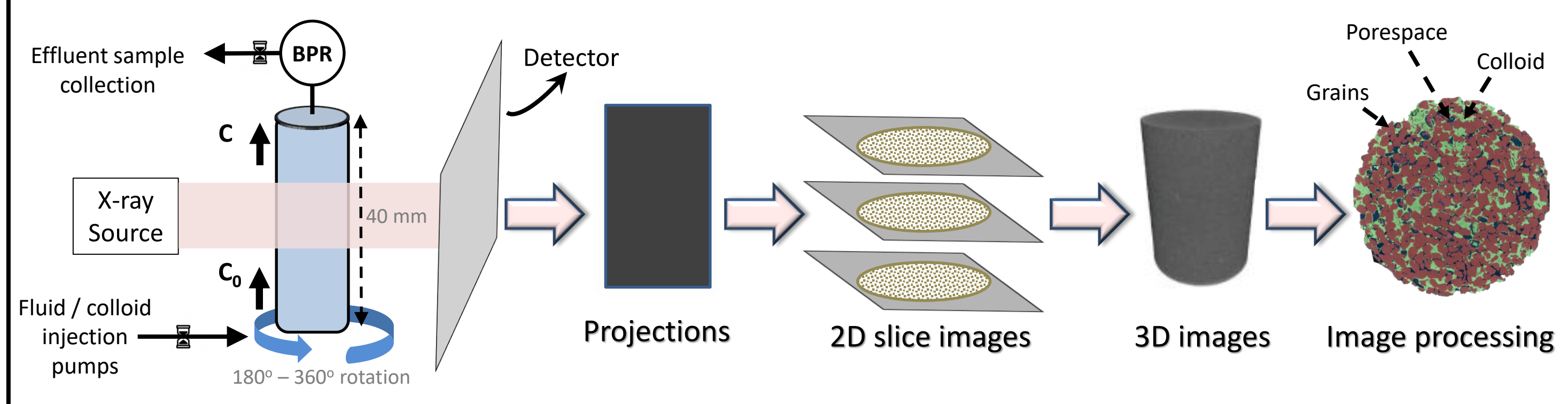
Flow-through experiments

- Upscale pore-scale dynamics using cylindrical samples of porous sintered glass with average pore throats in the range 30–70 μm.
- **Hypothesis:** Colloid deposition can clog pores and alter hydrodynamic forces which aid NAPL removal.



4D X-ray micro computed tomography

- X-rays enable high-resolution, non-destructive imaging at the pore-scale [6].
- We use time-resolved 3D X-ray micro-tomography to investigate colloid transport, pore clogging and flow modification under transient conditions.



Laboratory-scale



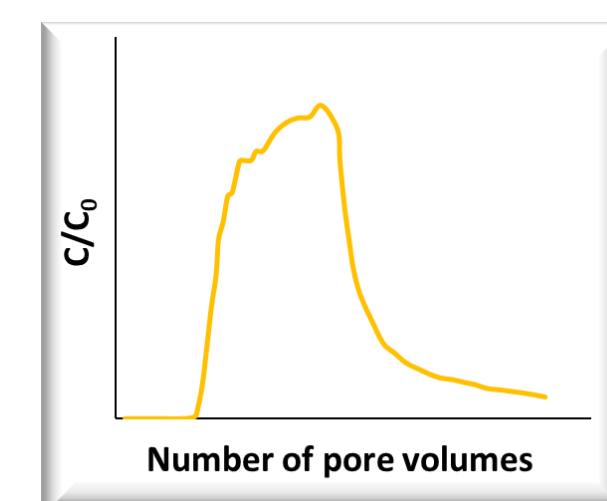
Synchrotron radiation



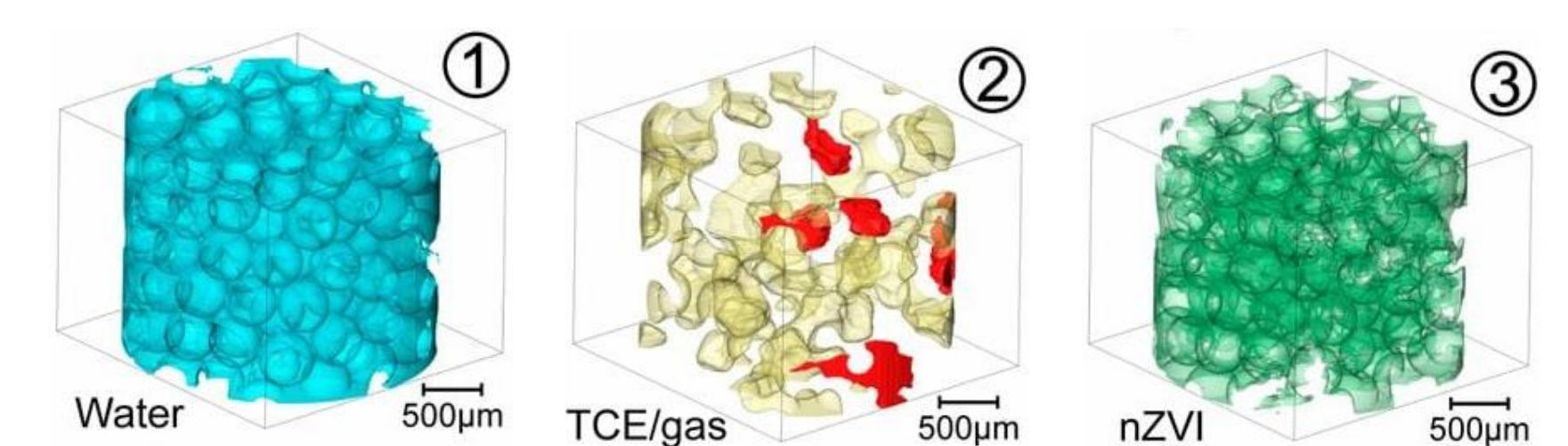
Expected results

- Provide distribution and evolution of pore clogging due to colloid deposition.
- Quantify NAPL remobilization induced by pore clogging.
- Provide high-quality 3D images to uncover hydro-electro-chemical processes.
- Provide optimized fluid injection strategies for groundwater remediation.
- Refine multi-scale flow and particle transport prediction using OpenFOAM [7].

Colloid breakthrough curves



Fluid / colloid redistribution



Summary

- Understanding the fate of colloids in porous media, such as rocks and soils, is crucial for environmental and geophysical applications including groundwater remediation.
- Colloids play an important role in mobilizing contaminants in subsurface systems. Limited knowledge on the mechanisms controlling colloid retention and transport hinders their widespread use.
- We propose time-resolved 3D X-ray micro-tomography to investigate colloid deposition, pore clogging and flow modification processes which aid NAPL removal.

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