

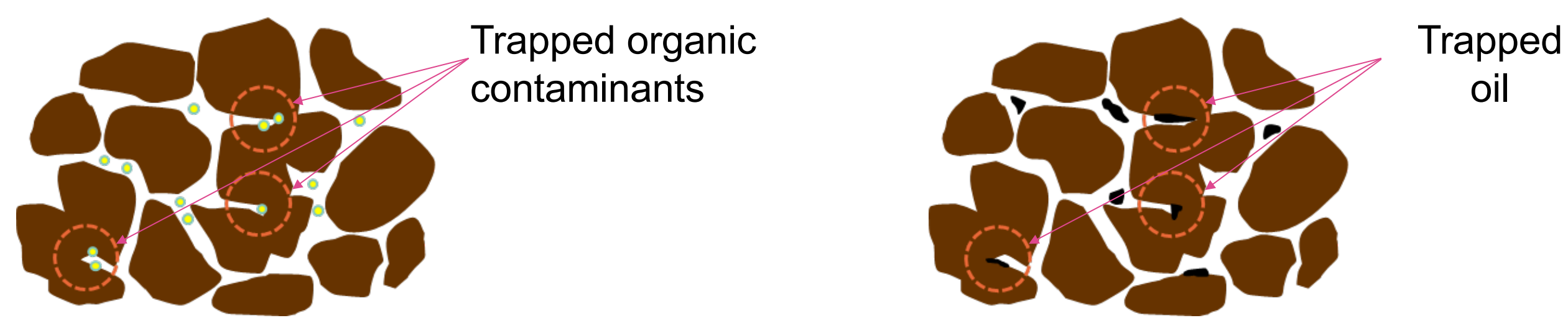
# Autonomous Nano-capsules for Subsurface Remediation and Energy Harvesting Applications

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## Objective

-Dead-end channels exist in nature and are common in all subsurface geological formations



-Deliver nanoparticles and chemical nanocapsules into dead-end channel by **diffusiophoresis (DP)**



-Diffusion:

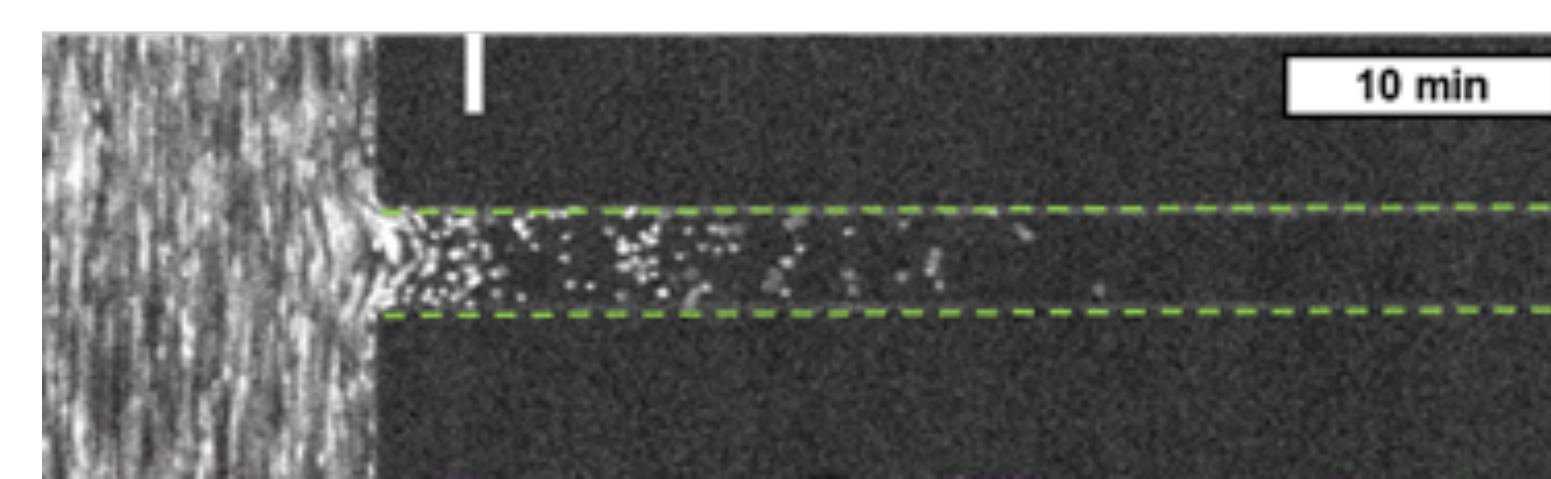
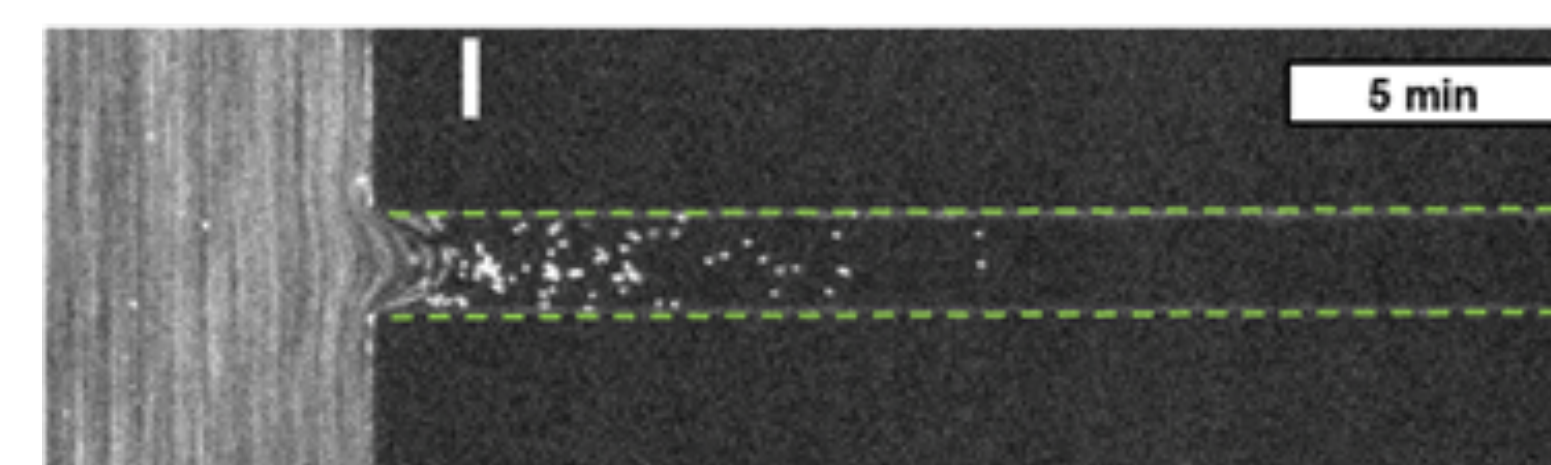
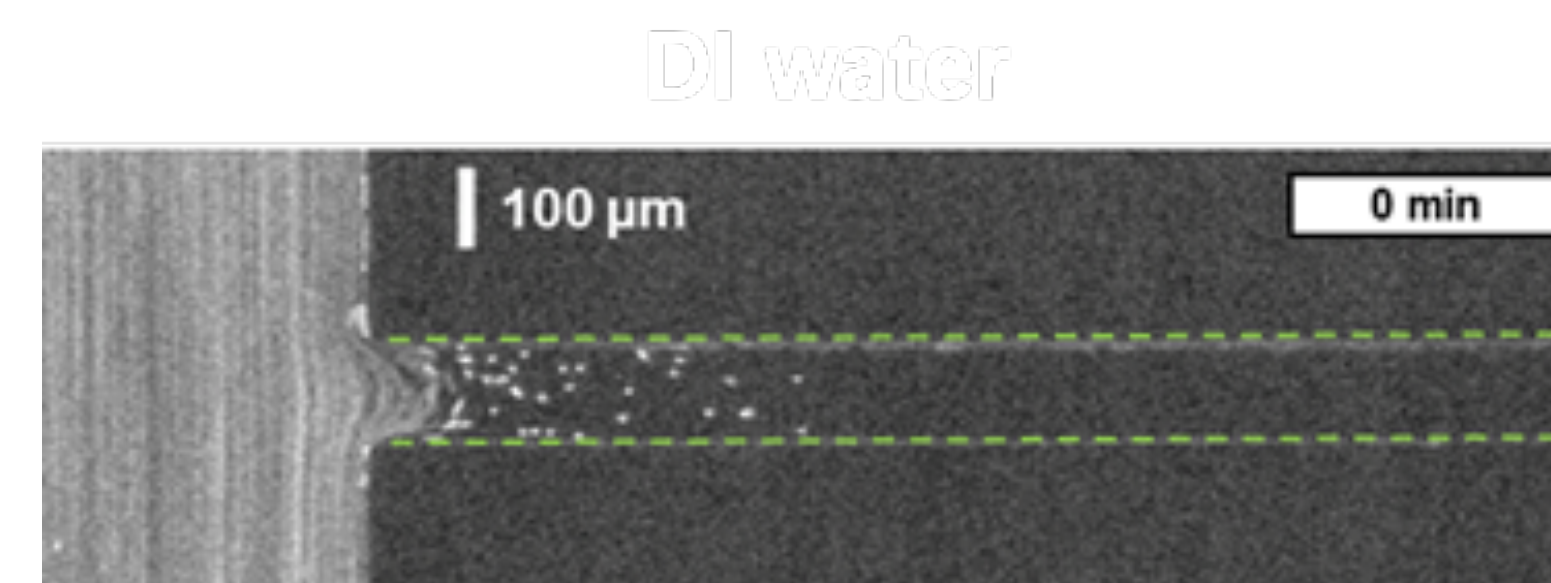
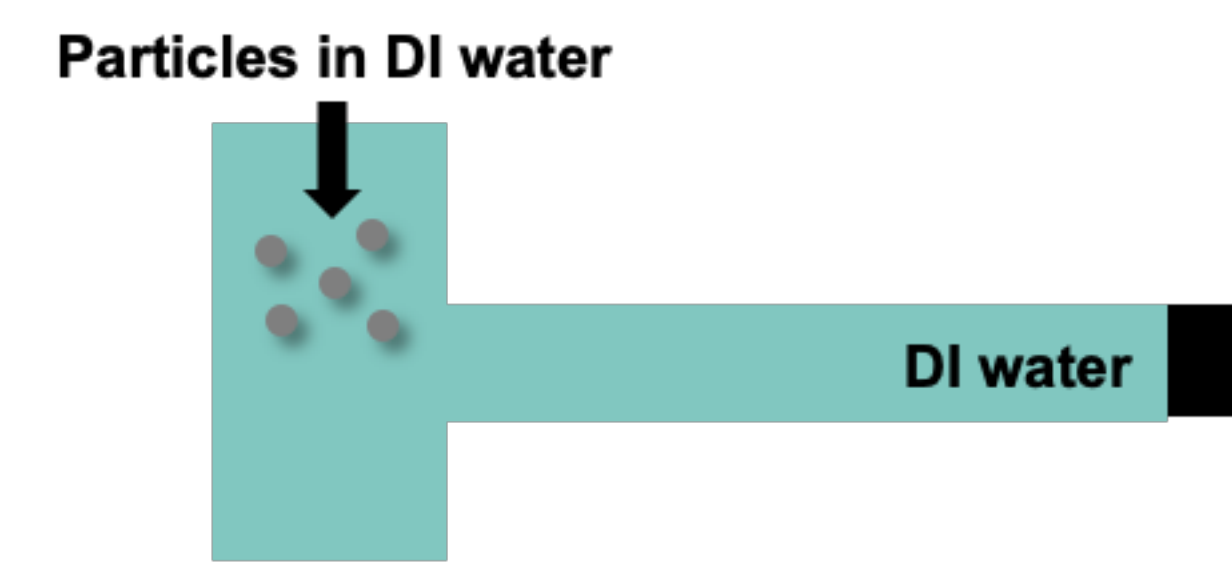
1- $\mu\text{m}$  particle takes two months to diffuse 1mm in water  $\rightarrow$  long time

-Pressure-driven flow:

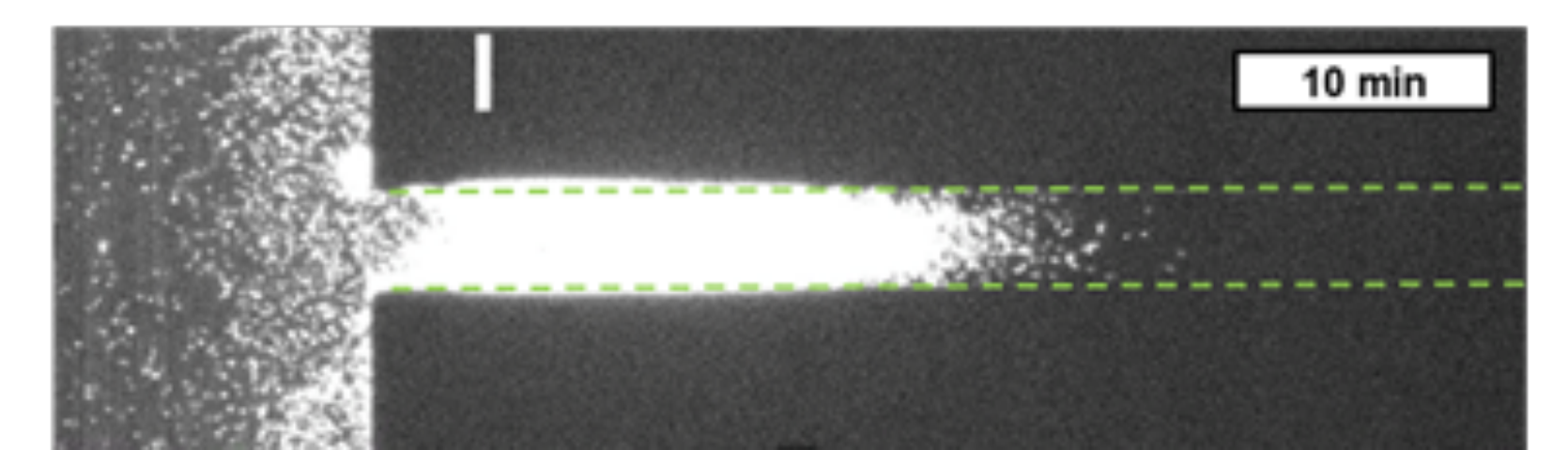
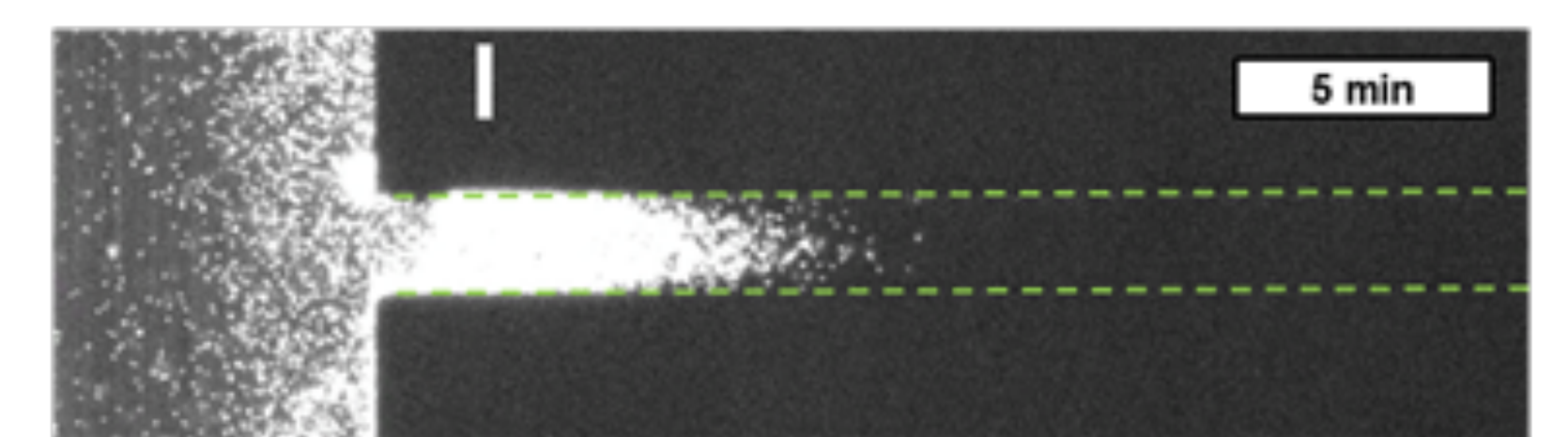
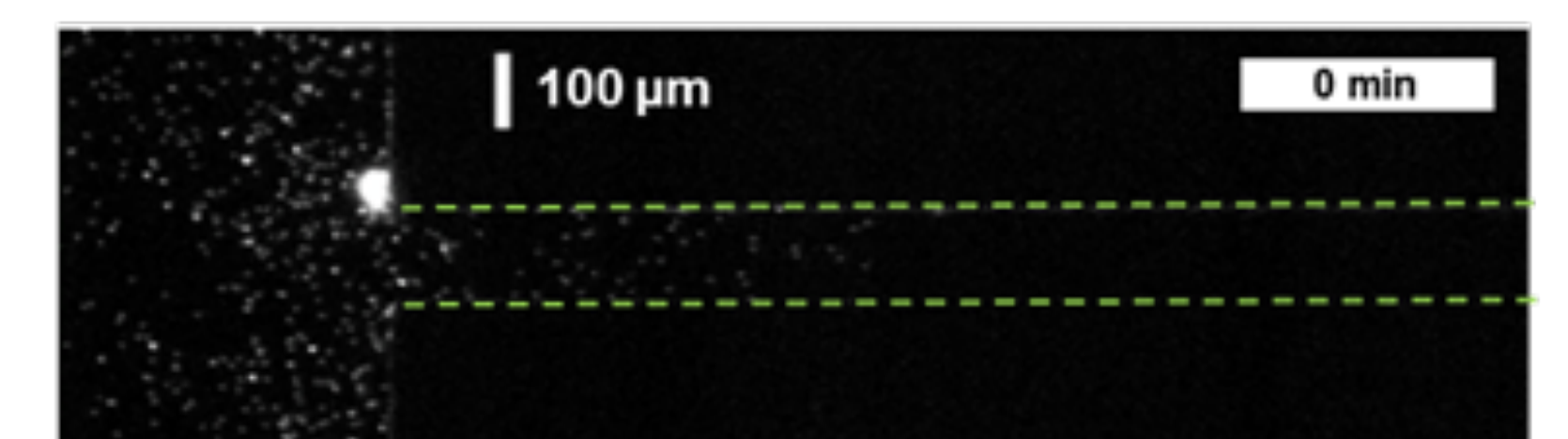
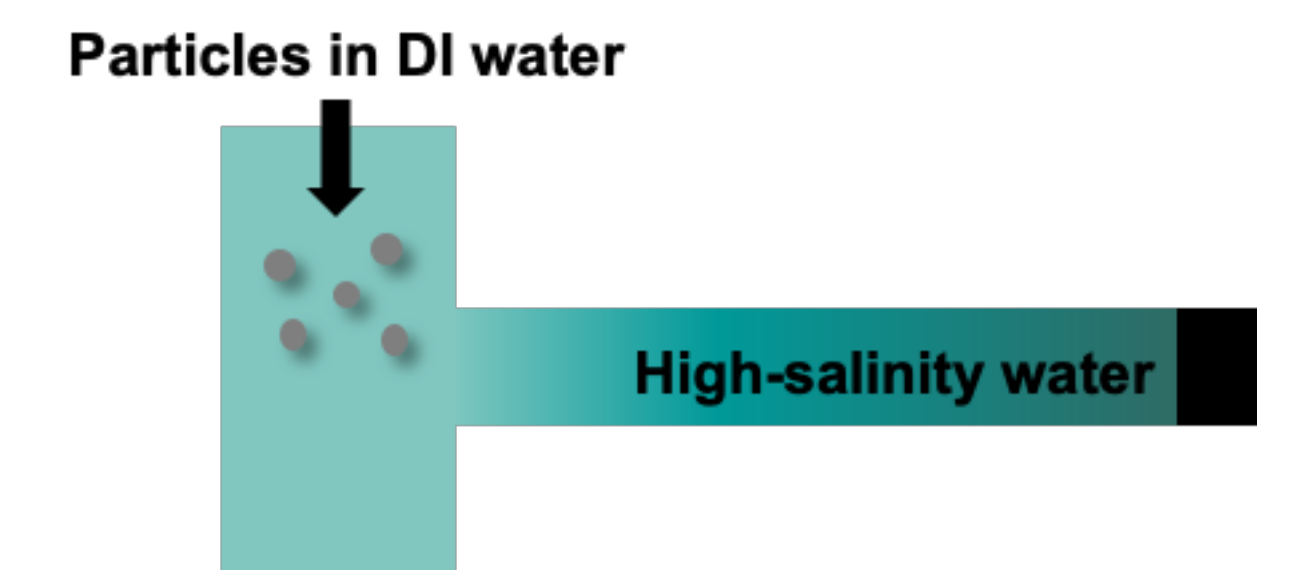
Large flow resistance

## Results

-No gradients

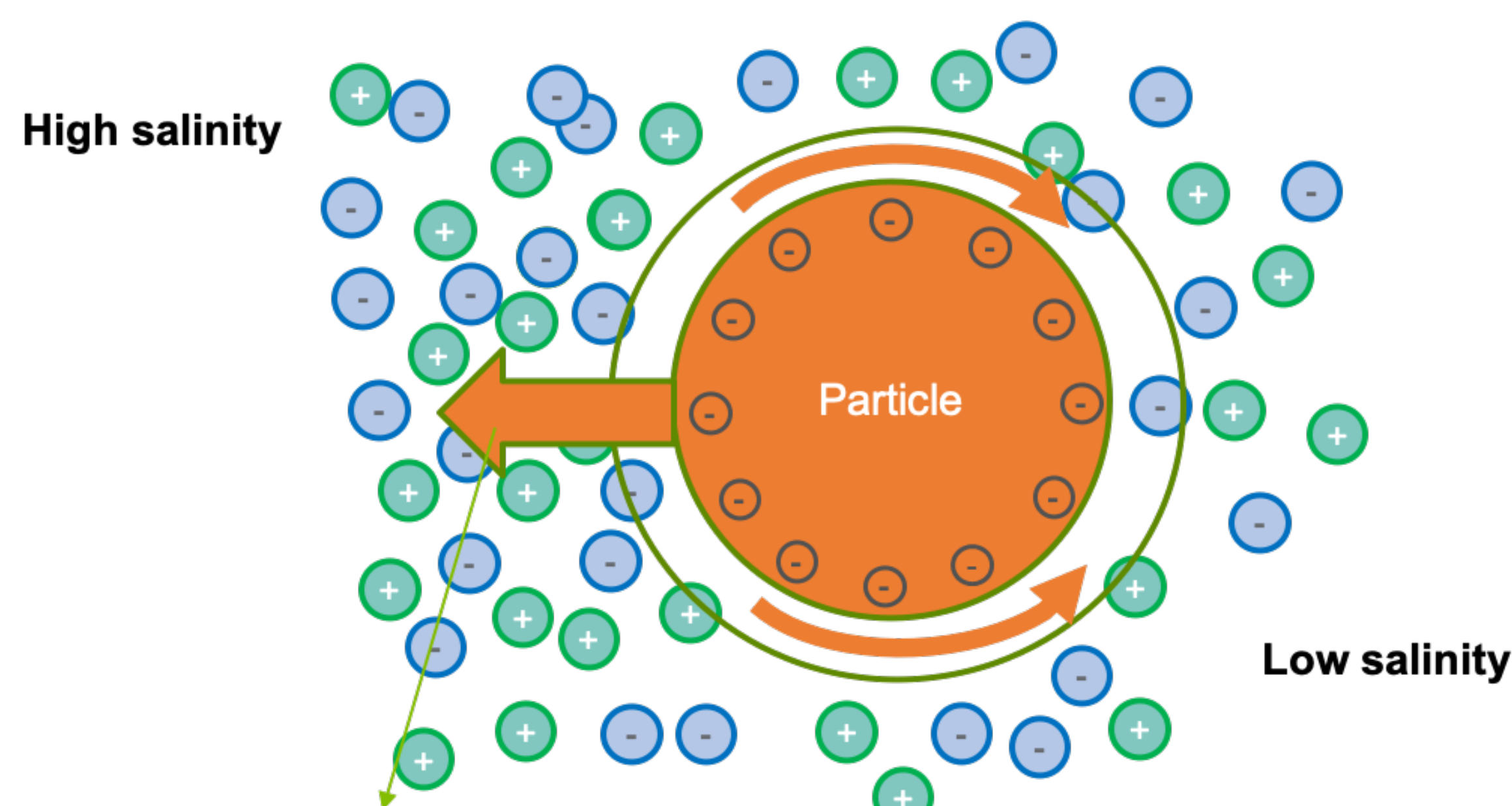


-Salinity gradients



-Particles migrate faster under salinity gradients

## Diffusiophoresis (DP)



$$4 \frac{\epsilon}{\mu} \left( \frac{kT}{e} \right)^2 \ln \left[ \cosh \left( \frac{e\zeta}{4kT} \right) \right] \nabla \ln c_\infty + \frac{\epsilon\zeta}{\mu} E_\infty \quad E_\infty = \frac{D_+ - D_-}{D_+ + D_-} \frac{kT}{e} \nabla \ln c_\infty$$

## Benefits and Impact

-Chemical treatments are encapsulated, target-delivered and released where they are most needed in the subsurface formation  $\rightarrow$  Less chemicals, same result

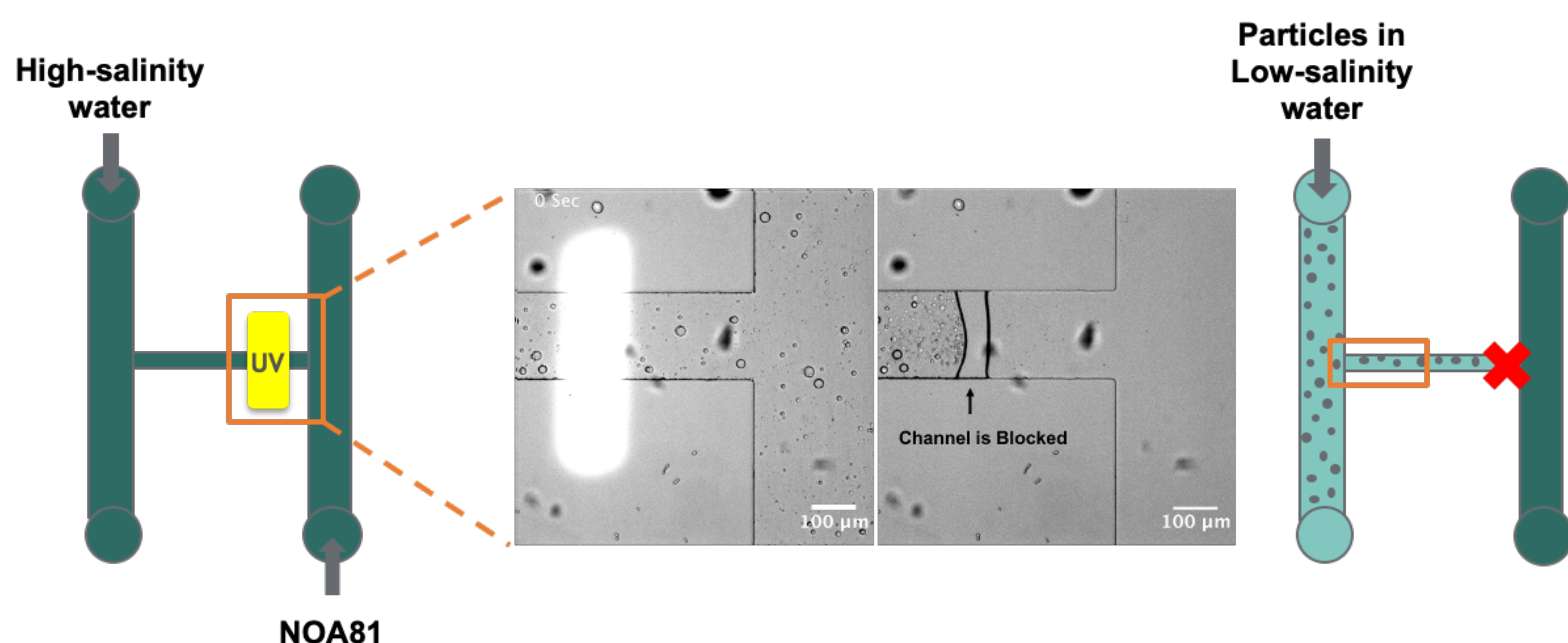
-Nanocapsules travel autonomously to target regions in the formation via harvesting existing natural gradients, and without pumping  $\rightarrow$  Less energy consumption, deep penetration

-Better accessibility to isolated tight-pore regions with trapped oil or contaminants  $\rightarrow$  Better recovery, higher efficiency

-Orders of magnitude faster delivery compared to diffusion  $\rightarrow$  Accelerated results, higher efficiency

## Experimental Set up

-Gradients are established in microfluidic channels mimicking dead-end pores in subsurface environments



## Target Applications

- Enhanced and improved oil recovery (EOR/IOR)
- Remediation groundwater aquifers with NAPL and DNAPL contaminants
- Scale inhibition and removal
- Subsurface sensing
- Lost circulation of drilling fluids

## Conclusion

Our results demonstrate the concept and provide evidence of the potential of utilizing existing chemical gradients to enable autonomous and sustainable migration of nanocapsules into constricted regions in the subsurface environment for more efficient and environmentally-friendly subsurface remediation and energy harvesting applications