Controlled alkaline degradation of HCHs for the *in situ* remediation of a high velocity anisotropic aquifer: from lab to field

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Session 6: LNAPL and Chlorinated compounds remediation
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Context

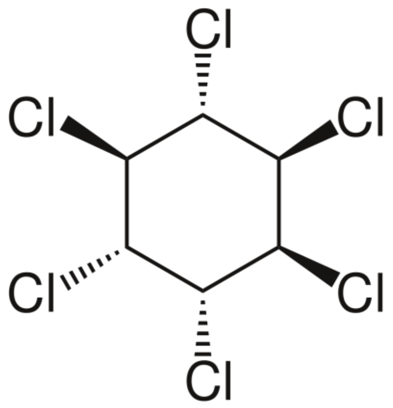
This work is part of the FAMOUS project co-founded by the French Environment & Energy Management Agency

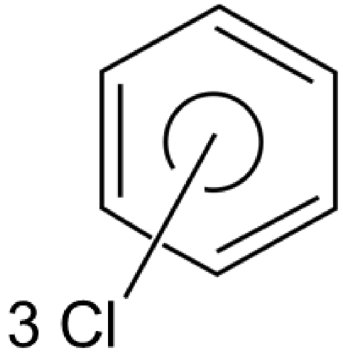
Develop and assess new technologies for the remediation of anisotropic high-velocity aquifers contaminated by chlorinated compounds

Context

Study site is an active chemical plant where was observed:

- High permeability anisotropy: $10 < K < 10^3$ D.
- Fast (u_{GW} ~ 10 m/d) and deep aquifer (~ 80 m bgs).
- Contamination by hexachlorocyclohexanes (HCH) and trichlorobenzenes (TCBs), probably mostly adsorbed, no known DNAPL.



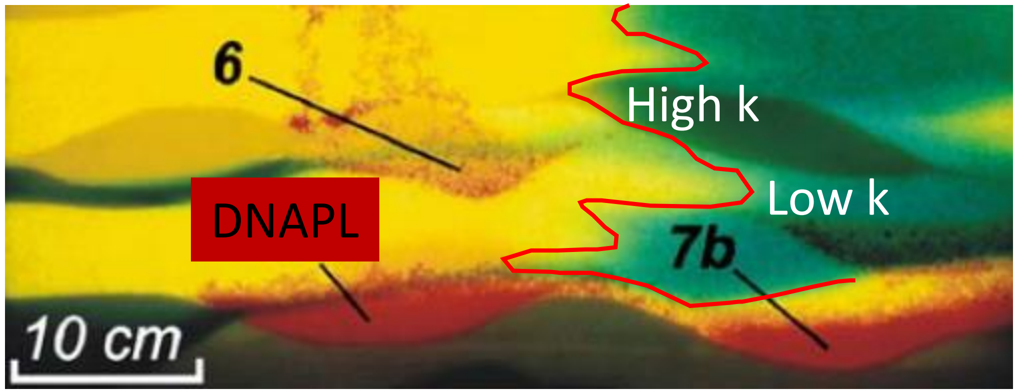


In situ remediation : access to contaminants is hindered

Context

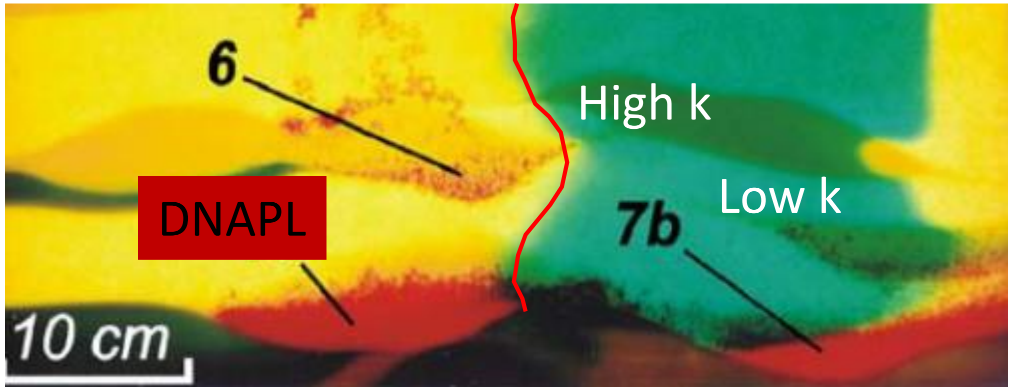
In situ remediation

Water



- Uncontrolled radii of influence
- Fingering
- Preferential flows
- heterogeneous distribution of amendments

Polymer solution

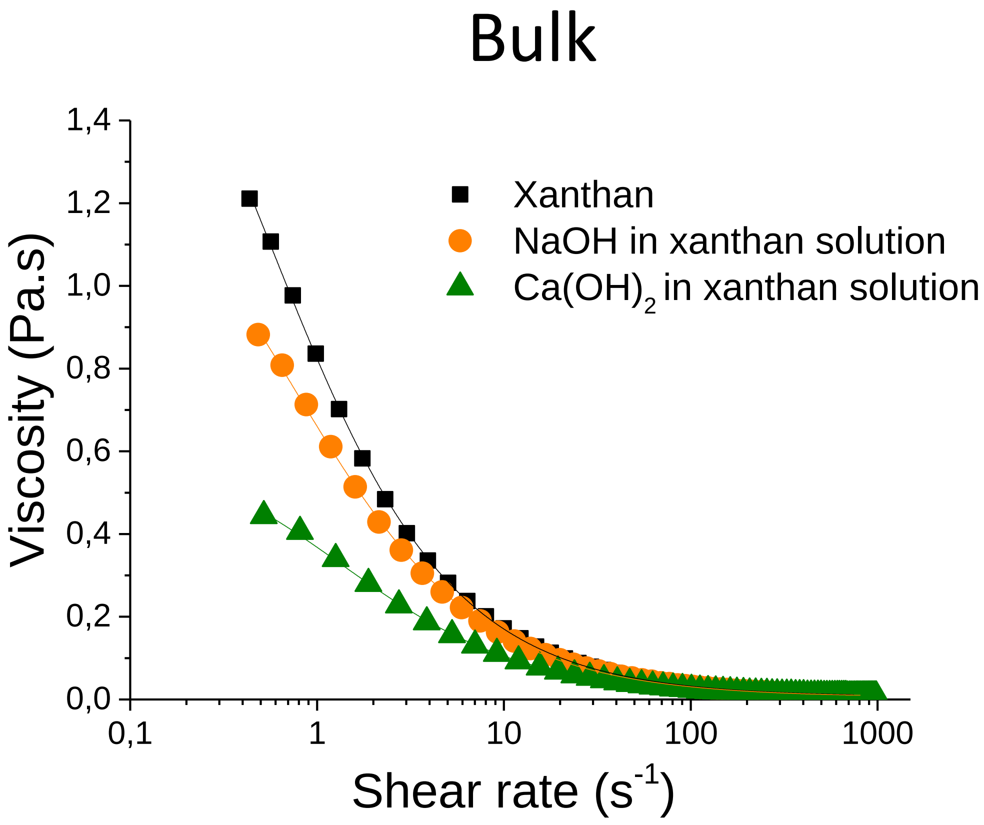


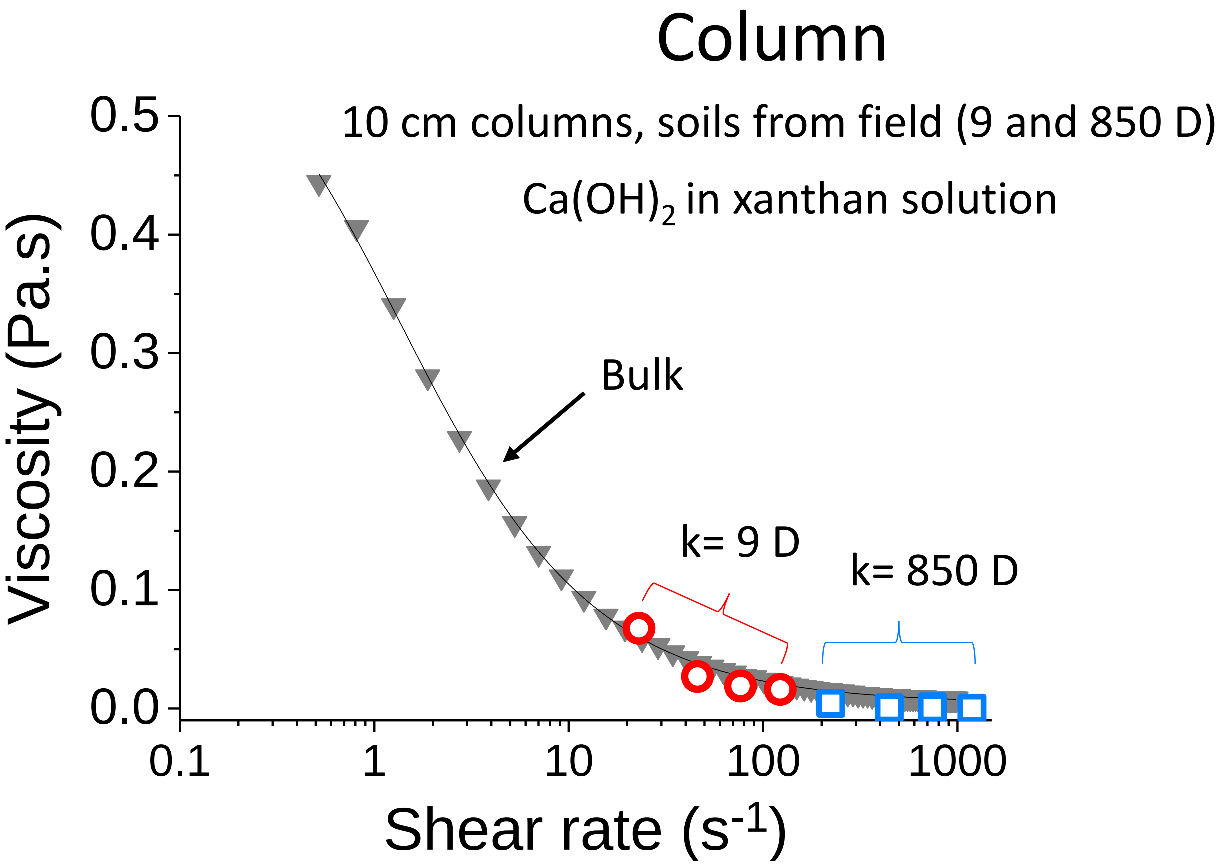
Robert et al., 2006

- High viscosity, shear-thinning
- No fingering
- Flat front propagation
- Isotropic distribution of amendments despite k-contrast

➔ Use of xanthan solutions to deliver persistent alkali (*in situ* dichlorination, pH 12) and maintaining action by blocking the GW flow + degradation kinetics of the contaminants at pH 12

Rheology of xanthan solutions : bulk and column measurements





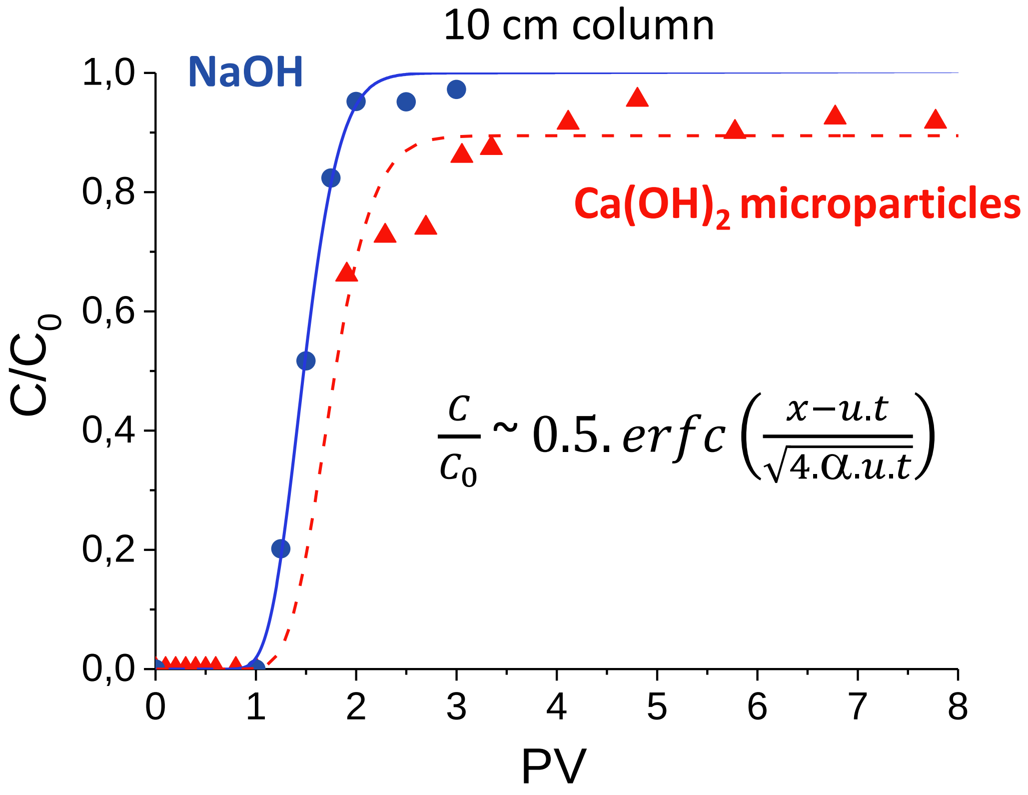
Cross model $$\eta = \frac{\eta_0 - \eta_\infty}{(1 + \lambda\dot{\gamma})^m} + \eta_\infty$$

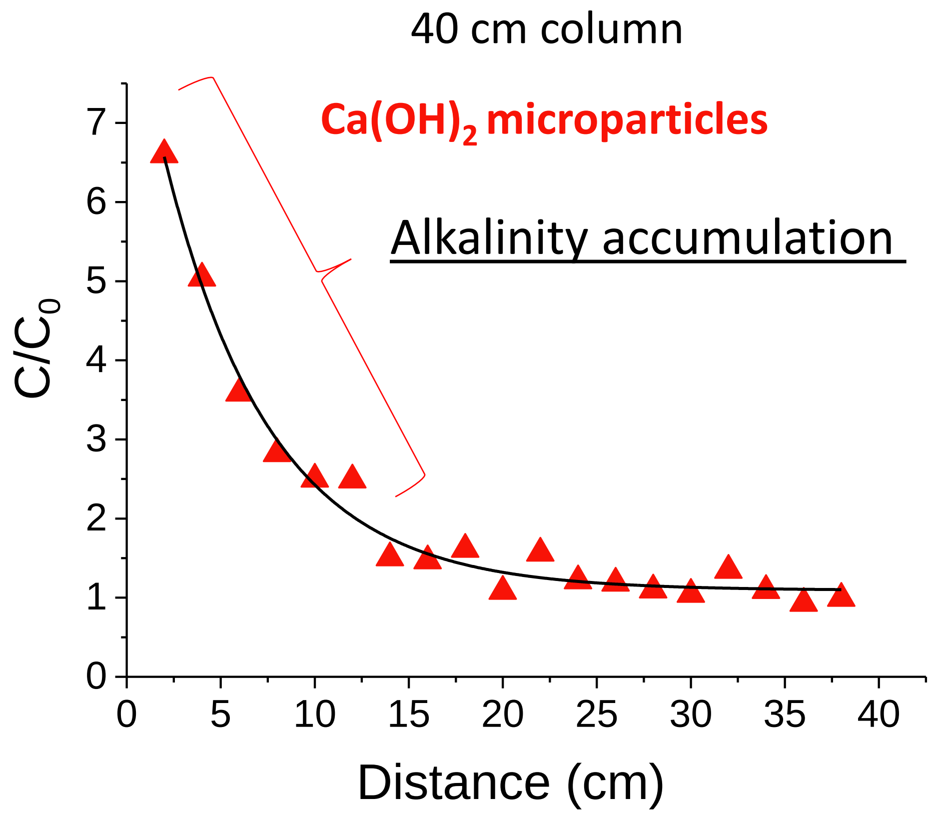
$$\eta_{app} = \frac{k}{u}\,\frac{\Delta P}{l}$$

$$\dot{\gamma_{mp}} = \frac{\beta \,.\, u}{\sqrt{k \,.\, \varepsilon}}$$

Alkalinity breakthrough curves using xanthan solution

contaminated fine material from field (9 D)



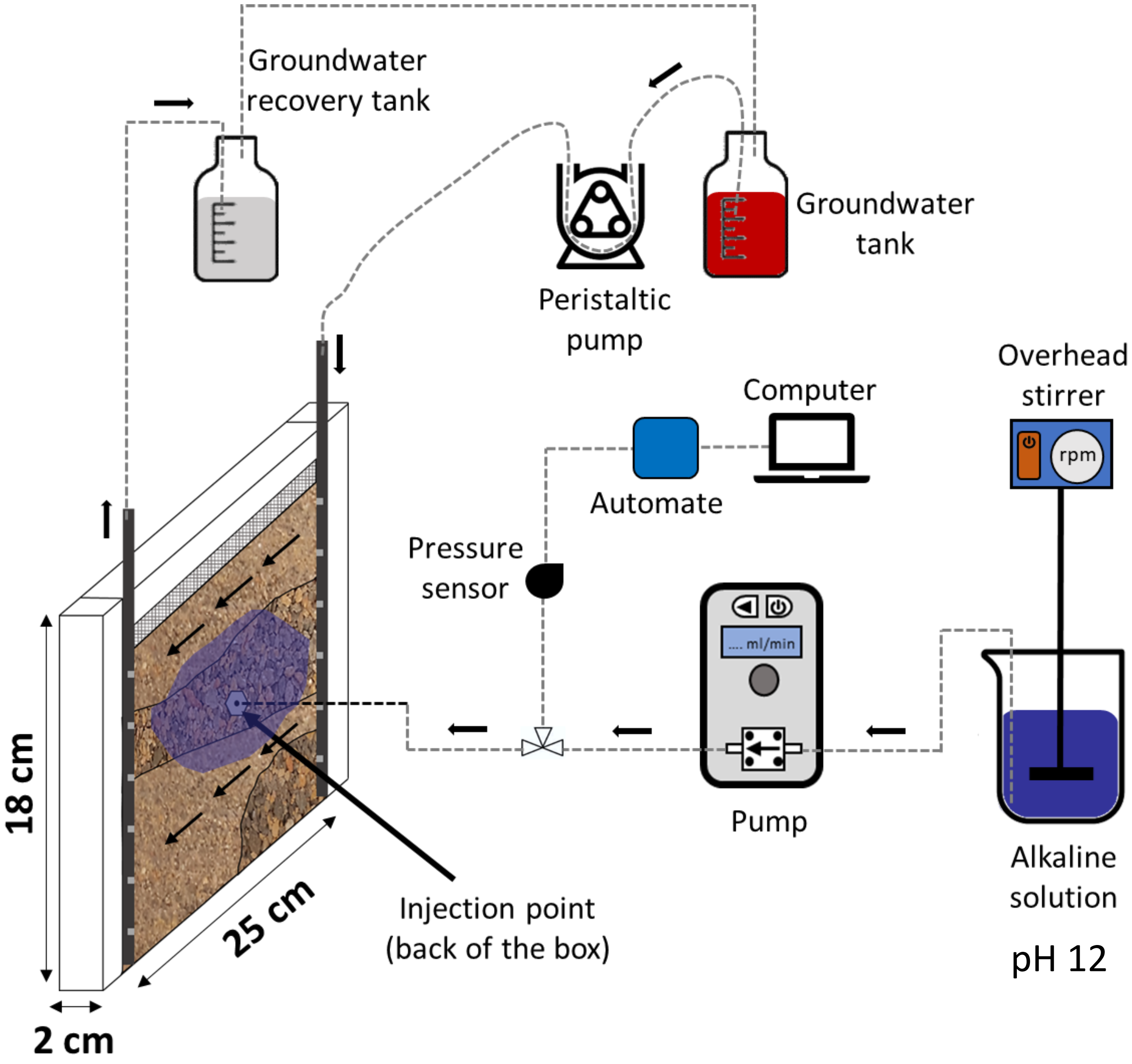


$Ca(OH)_2$ microparticles:

- Retardation factor of 1.2
- Alkalinity transmission : 91%

Accumulation of alkalinity at the column input
→ delayed transmission of alkalinity due to the size of the $Ca(OH)_2$ microparticles

Measurements in permeability-contrasted sandbox: experimental set-up



Soils used:

Medium sand (95 D) **k-contrast : 8.7**

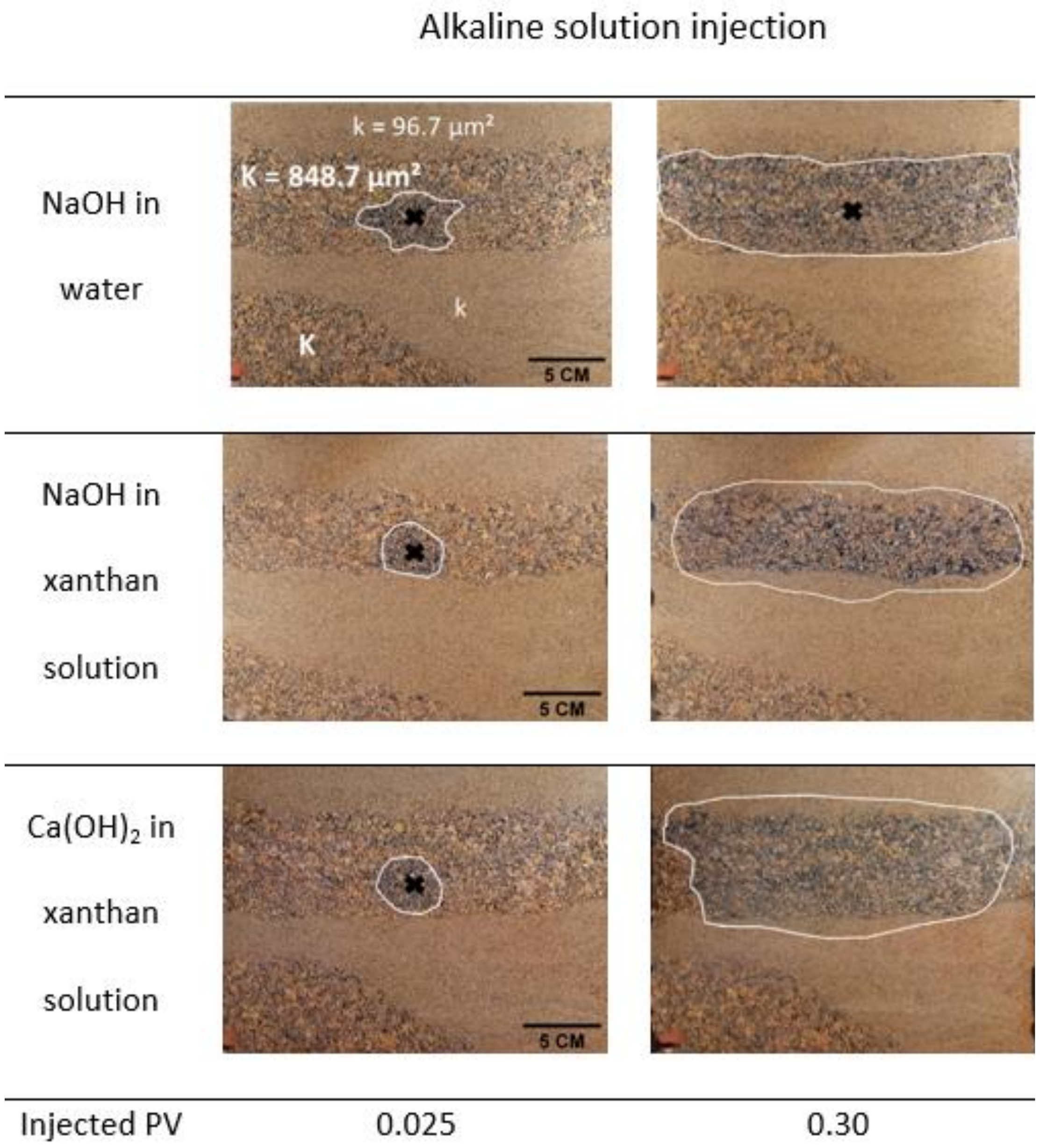
Coarse sand (850 D)

GW velocity : 10 $m.d^{-1}$

Injected fluidsat pH = 12

- NaOH in water (reference)
- NaOH in xanthan solution
- $Ca(OH)_2$ in xanthan solution

Measurements in permeability-contrasted sandbox: fluids comparison



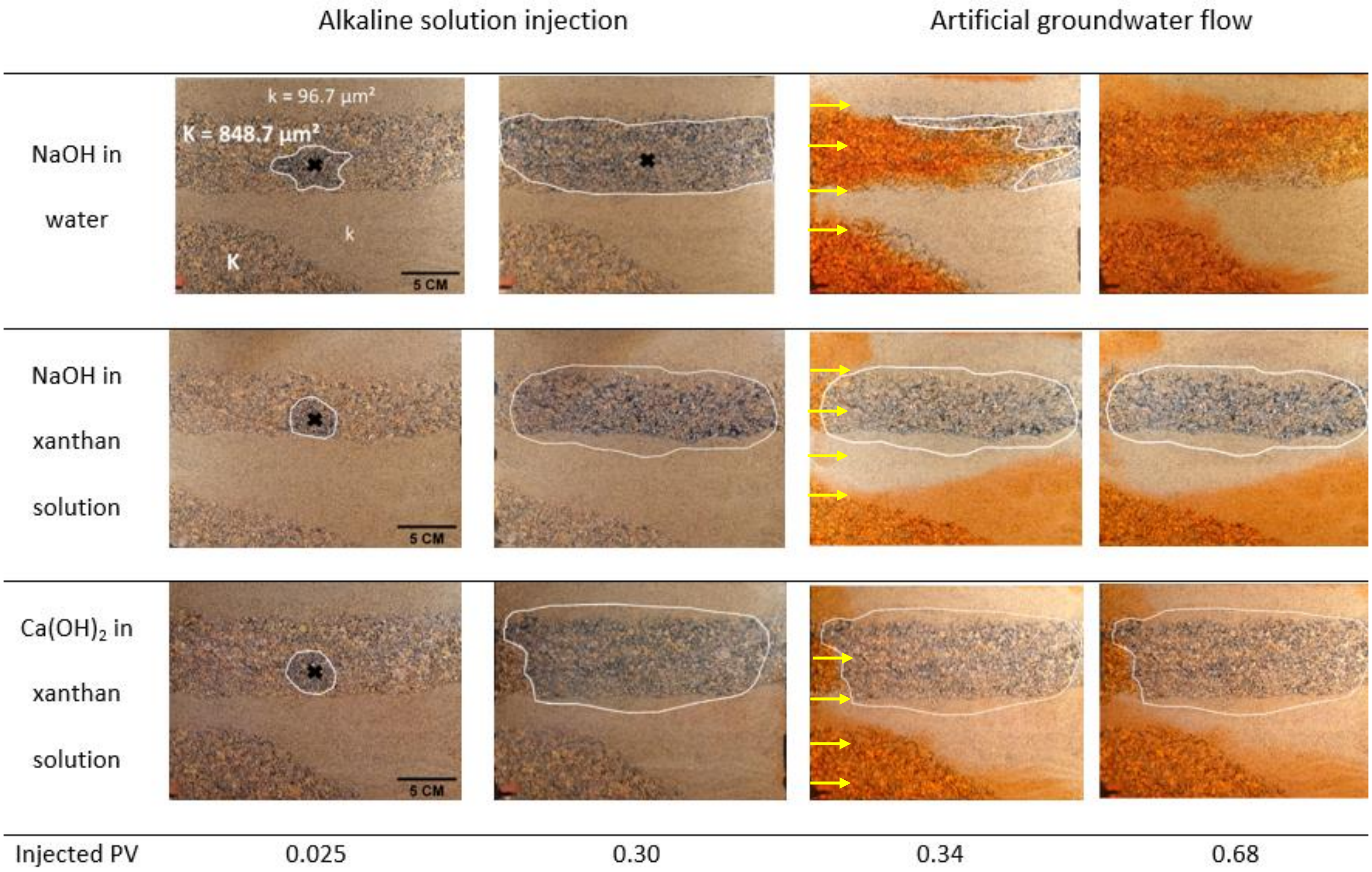
NaOH in water:

- Propagation only in the high permeability layer
- Fingering

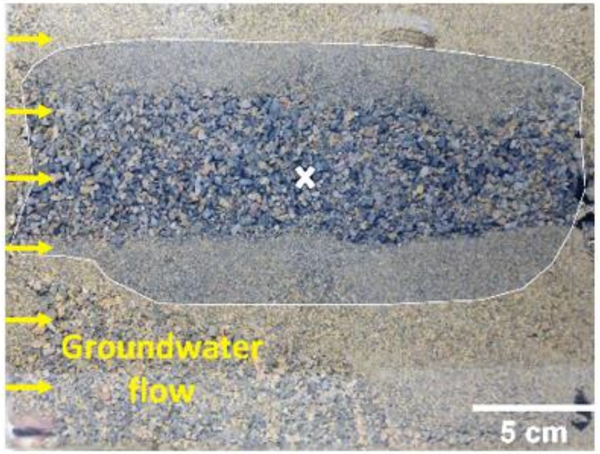
Xanthan-based fluids:

- Propagation in both permeabilities
- Flat front propagation : controlled delivery
- Better behavior of NaOH in xanthan due it's rheology

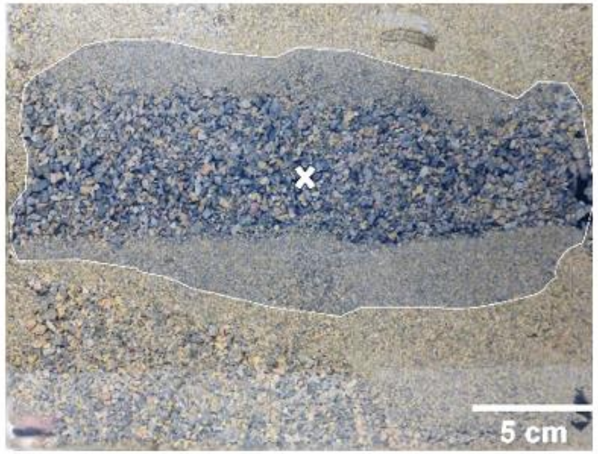
Measurements in permeability-contrasted sandbox: fluids comparison



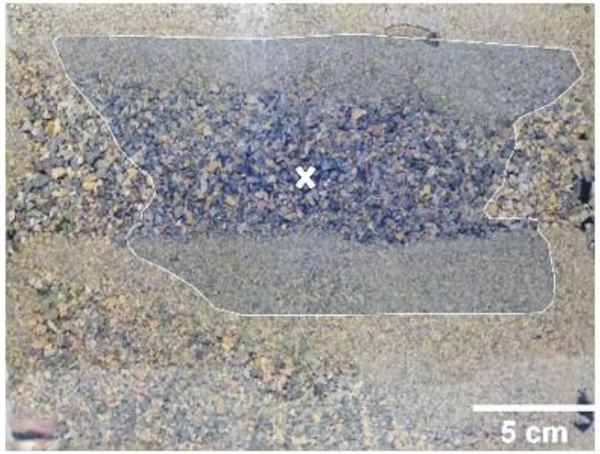
Measurements in permeability-contrasted sandbox: Persistence of $Ca(OH)_2$ in xanthan solution



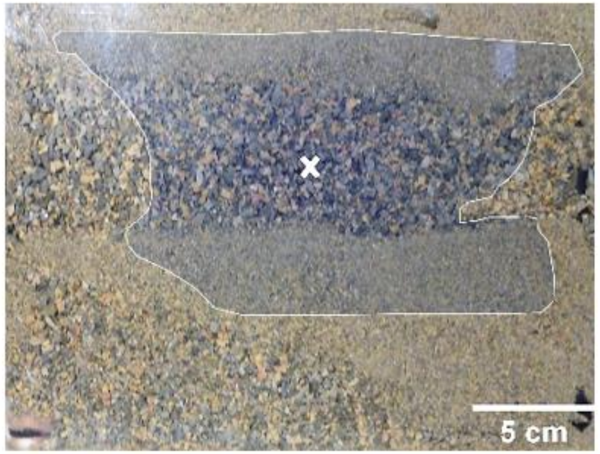
t_0



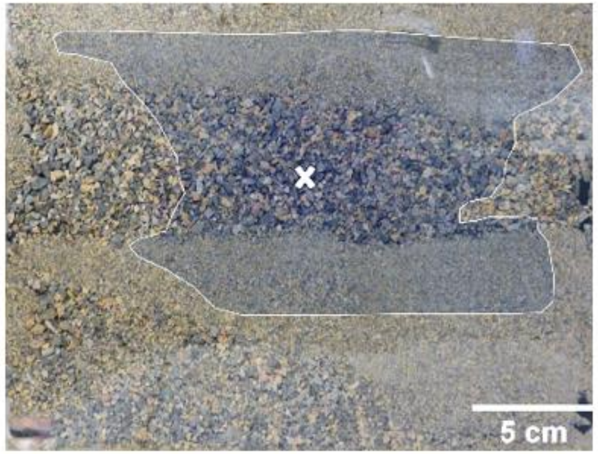
$t_0 + 5d$



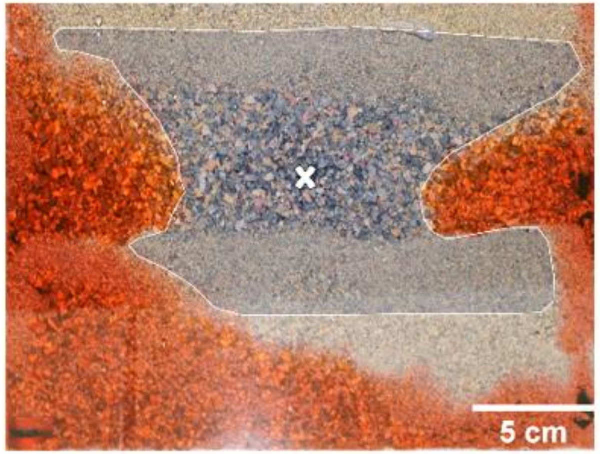
$t_0 + 10d$



$t_0 + 15d$



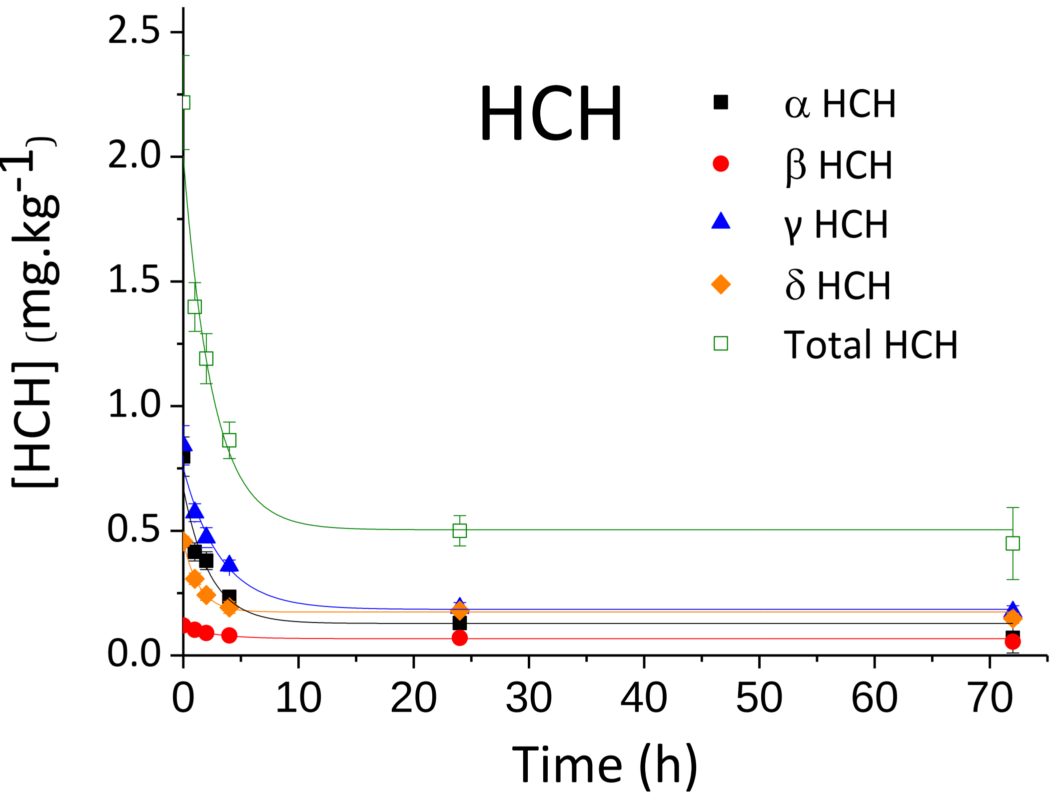
$t_0 + 16d$

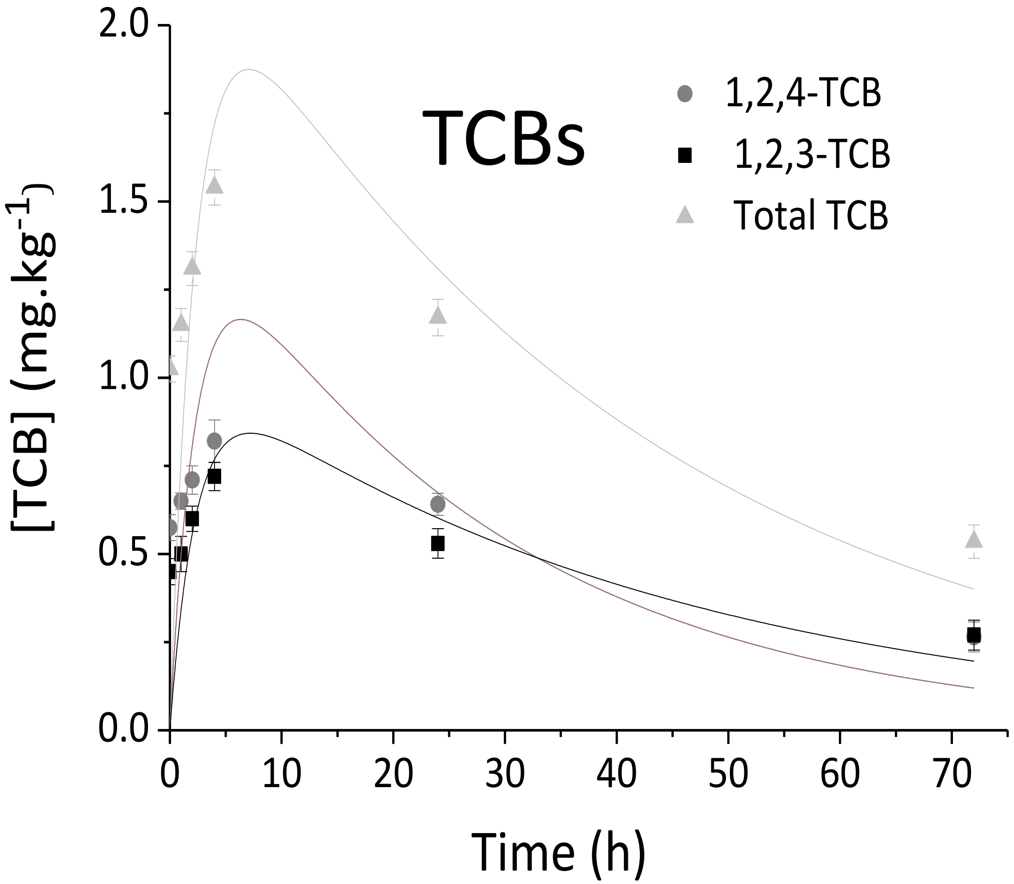


$t_0 + 18d$

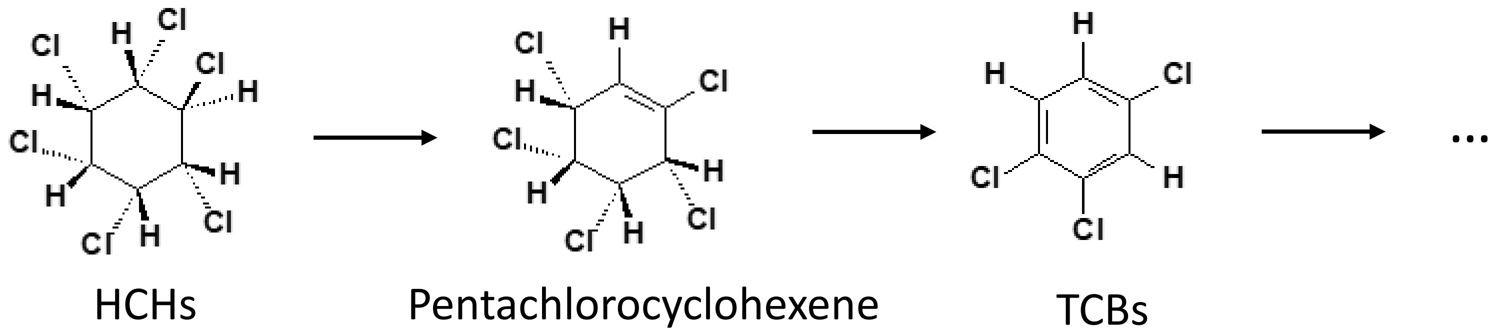
- Injection of more than 150 PV of GW
- Gel erosion velocity: 4.6×10^{-3} m.d^{-1}
- After 18d: 20% erosion of the treated zone

Kinetics and mechanisms of contaminants degradation ($Ca(OH)_2$, pH = 12)





Suggested pathway : dehydrohalogenation of HCHs to pentachlorocyclohexene followed by TCBs



Conclusions and perspectives

- Viscosity and shea-thinning behavior of xanthan was maintained despite the alkalinity and $Ca(OH)_2$ microparticles
- Lack of fingering and an enhanced delivery of alkalinity when using the gels despite anisotropy
- Breakthrough curves for the alkaline gels showed the fast and high transmission of the alkalinity at low pressure
- Injected xanthan gels demonstrated a persistent blocking effect in the treated zone and GW flow diversion
- At pH = 12, HCHs were converted into TCBs, which were further removed
- A monitored field-scale pilot (10x10m), with alkaline injections between 8 to 15 m in the contaminated GW was delayed because of Covid-19 and is planned for next year

Thank you !

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