The MOUSTIC project: Development and assessment of a new foam-based method for the enhanced (bio)degradation of hydrocarbons in vadose zone

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Soil Remediation

RemTech Expo 2019 Ferrara

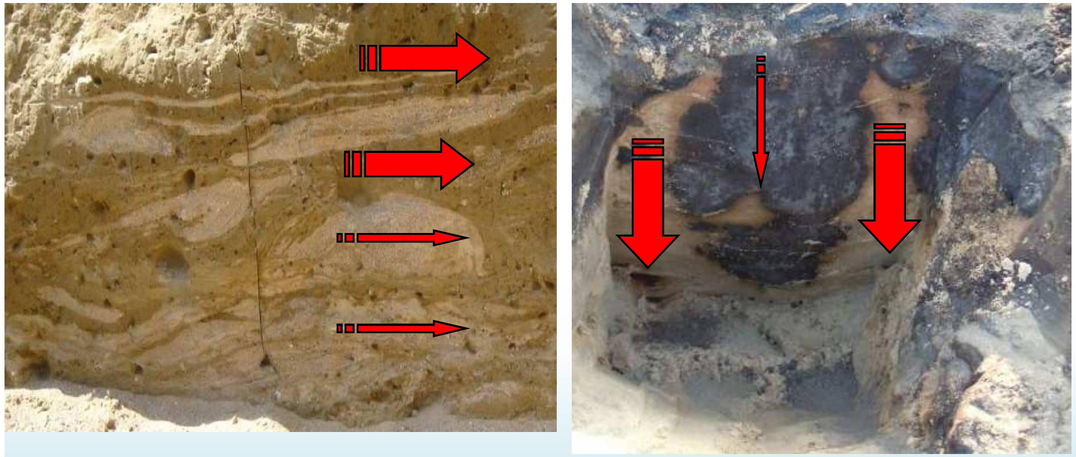
Context

***In situ* remediation limited by difficulties to warrant contact between amendment and pollution**

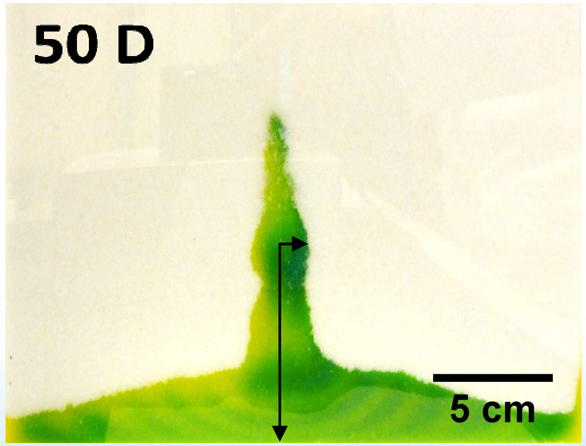
How to prevent preferential flows ?

How to make long lasting contact to slowly desorbing pollutants in vadose zone ?

Anisotropies of permeability and hydrophilicity



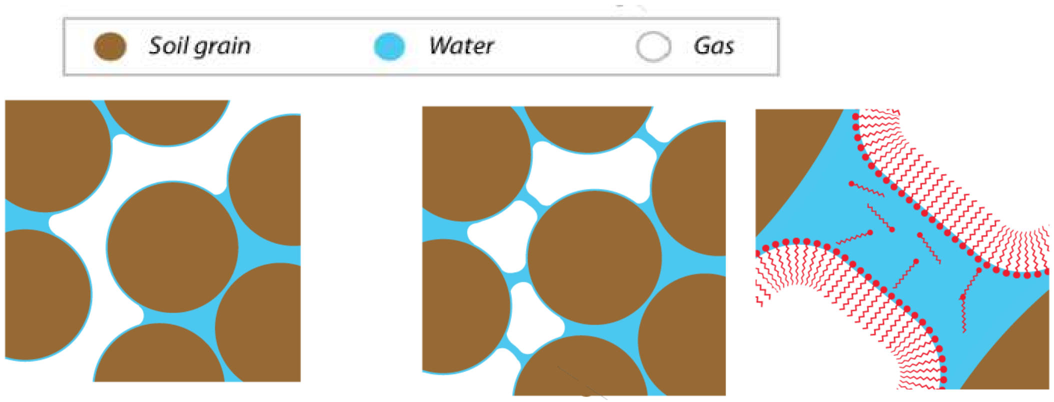
Gravity in vadose zone → vertical flow and low ROI



Liquid injection

√ Viscous fluids less affected by gravity and anisotropies

Foam in soils and sweeping



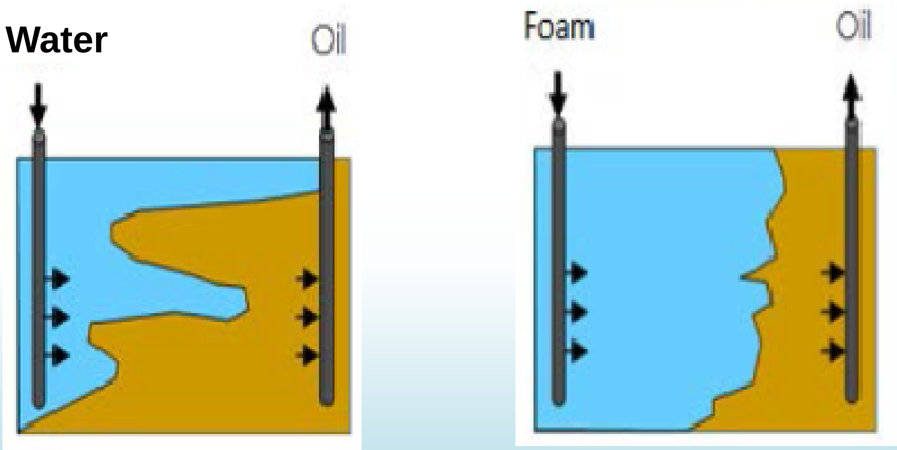
No foam:
continuous
gaz phase

Foam: Gas bubbles separated by water films stabilized by surfactant (lamellea)

High viscosity and low density
→ **Better sweeping**

Blocking of highly permeable zones
→ **Limit preferential flows**

EOR



Scarce reports of use for ISER
(Hirasaki, 1997; Maire, 2018, Portois, 2018 CC_contamin. groundwater)

Aim of Moustic

Tools and technologies for enhanced remediation of PH-contaminated anisotropic vadose zones using foam-based treatments

Consortium

Injection methods and chemical treatments
Coordinator

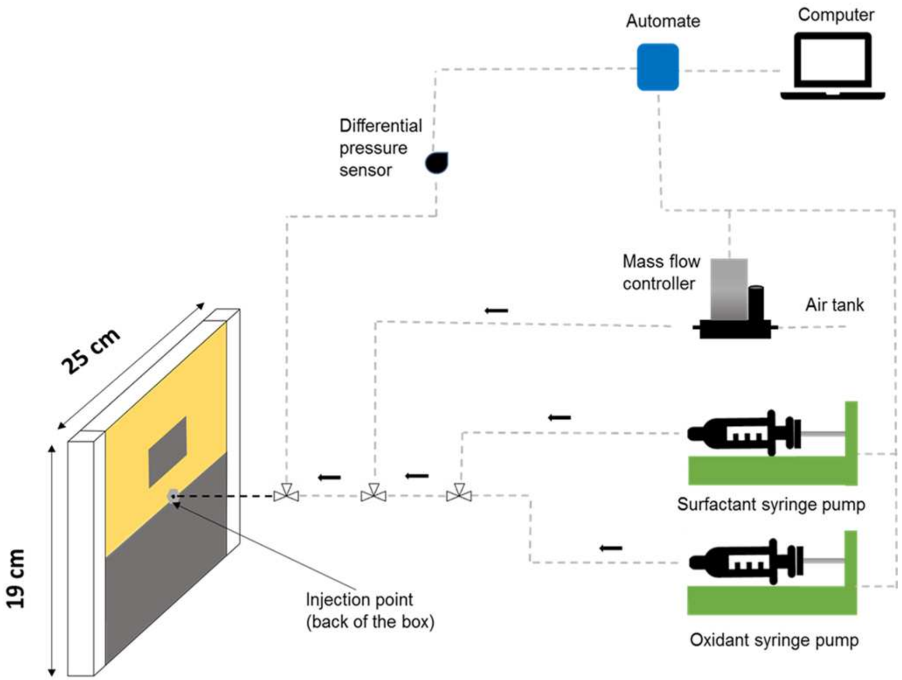
Biological and synergistic treatments

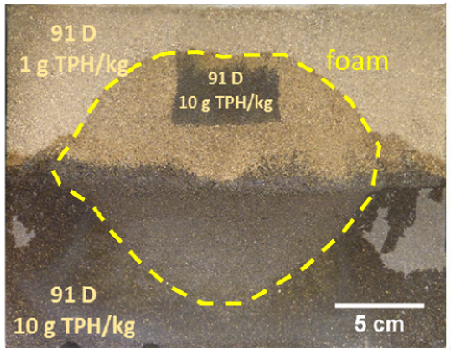
Field practitioners in remediation
→ Field tests

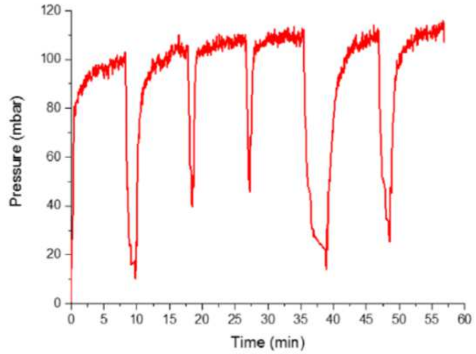
Engineering
→ Modeling of foam propagation and reaction kinetics

Moustic-anr.org

Experimental set-up for amendment delivery

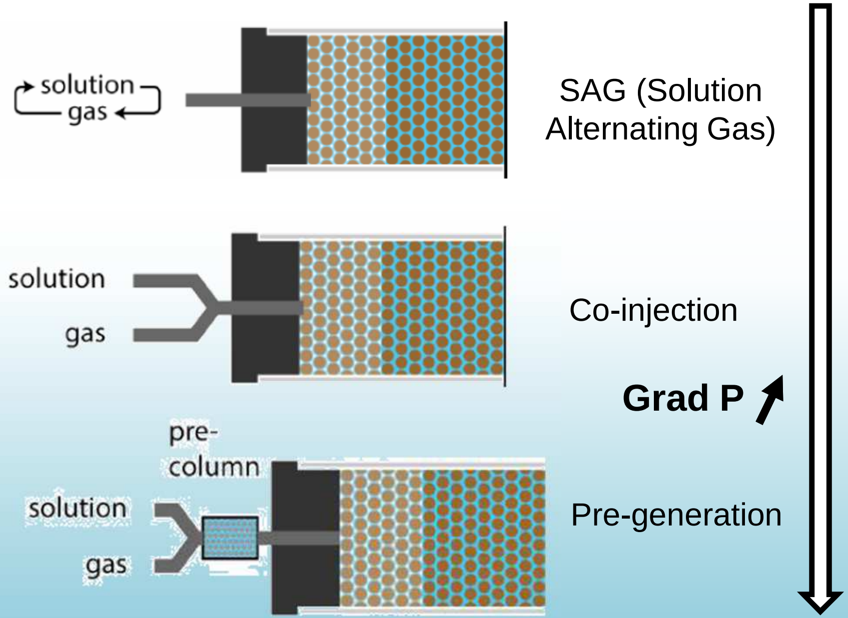






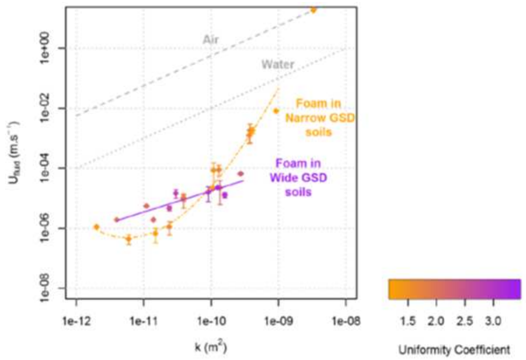
Injection methods

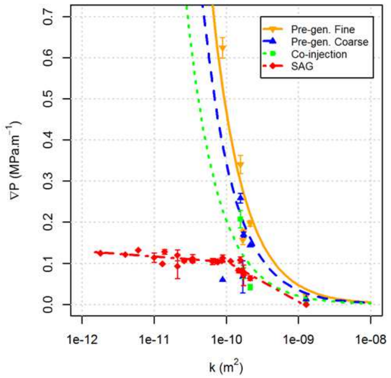
Caution:
Grad P < 1 bar/m
to avoid soil fracturing



Outputs

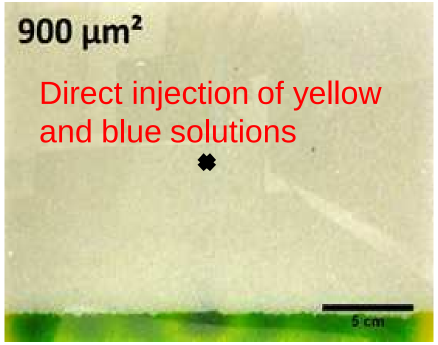
Forecasting foam rheology and injectability vs. soil characteristics

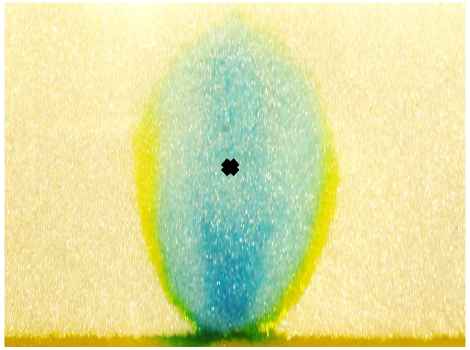




Maire et al., 2018

Prevent nasty interactions between surfactant and amendments

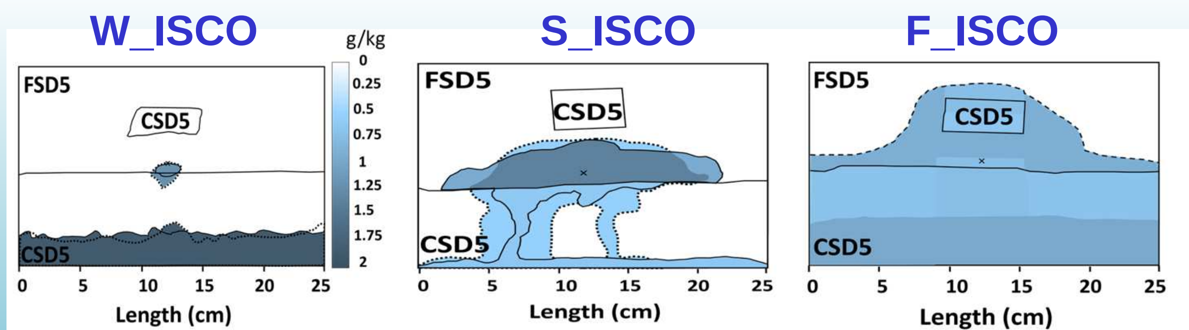




The method developed :
1) Foam injection (yellow)
2) Inject amendment solution (blue)

Bouzid et al., 2017, 2019

Lab-scale assessment and benefits *vs.* usual ISCO



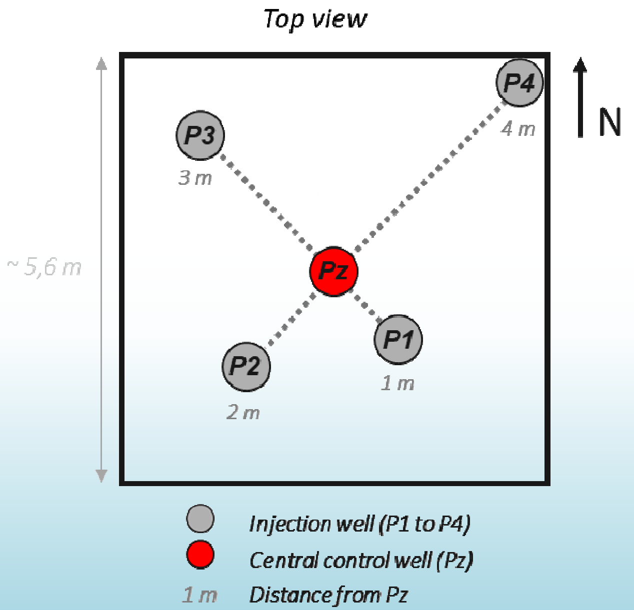
Improved :
- ROI and isotropy,
- Contact time,
- mineralisation

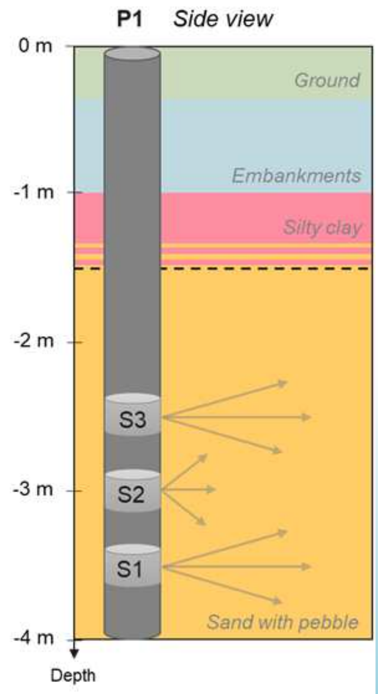
Bouzid et al., 2019a&b

Field characteristics and pilot-test

Fuel-contaminated zone

Lithology:
- Embarkment: 0.5 m
- Silty clay: 0.5 m
- Sand until saturated zone (9 m bgs)
k: 150 - 270 D
Porosity: 0.34
TPH 2-4 g/kg
PAHs 0.1-0.2 g/kg

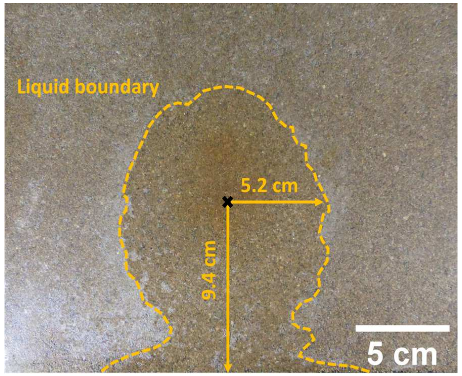


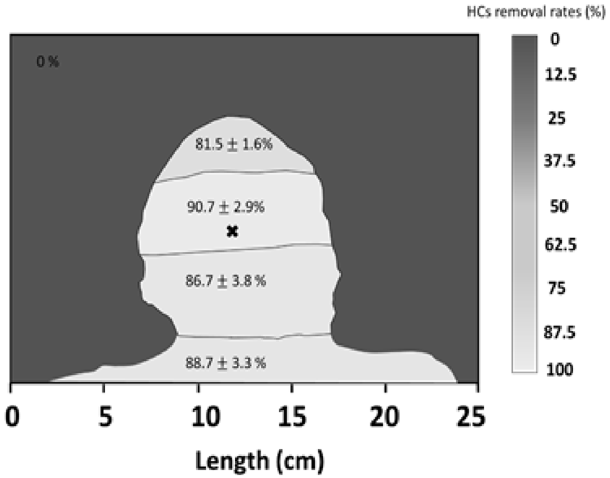


Treatability study at lab

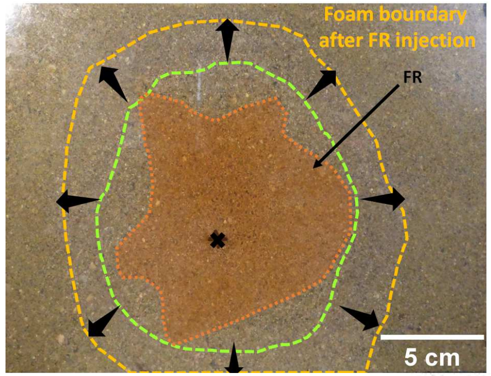
Assessment for Fenton reagent delivery (pH2) and ISCO effectiveness

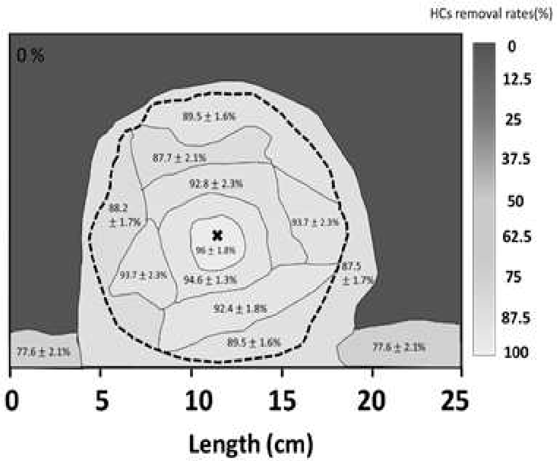
W_FR

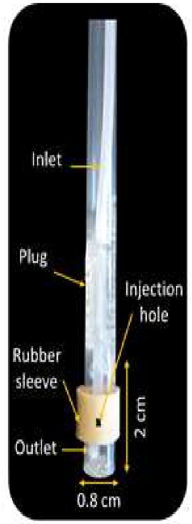




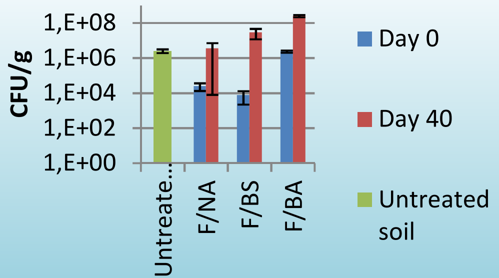
F_FR

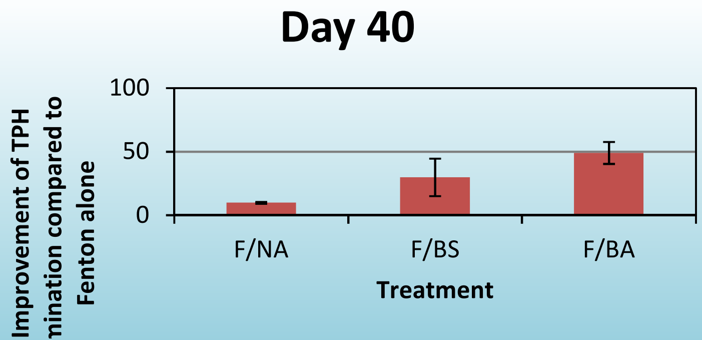




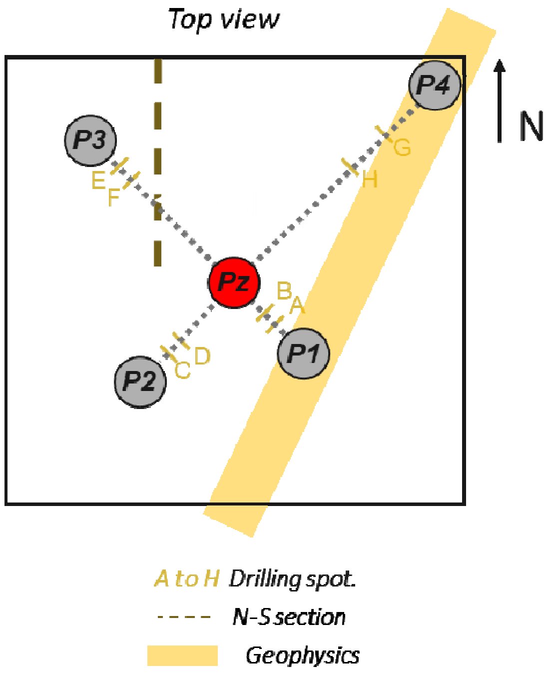


Synergistic degradations





Field-test



Treatment steps

A) Breakdown cement shells

P = 10 bars

0.5 m^3 / well

B) Foam injection

P = 2 bars

0.5 – 1.5 m^3 / well

C) FR injection

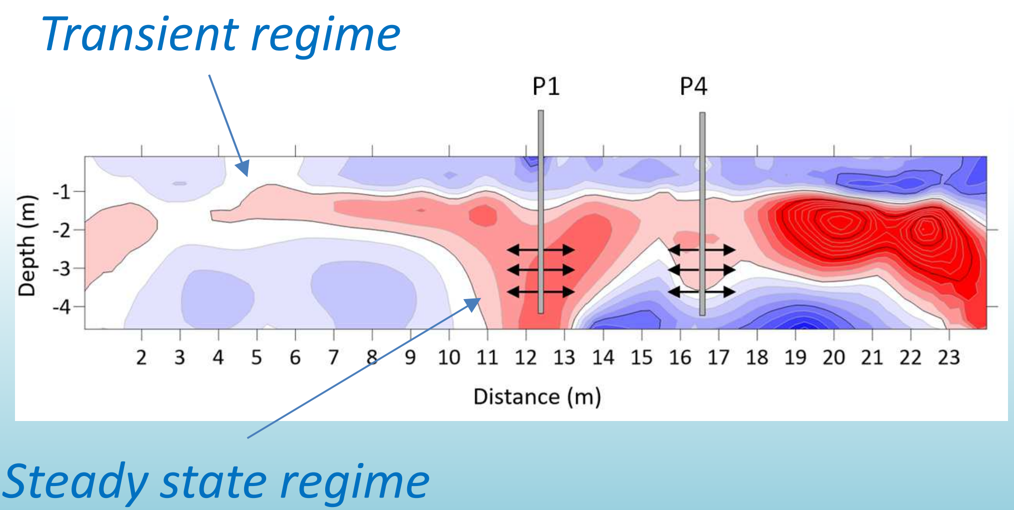
P = 5 bars

8 m^3 1.5% Fe(II) *pH 5*

4 m^3 4% H_2O_2

D) BS or BA

Monitoring foam



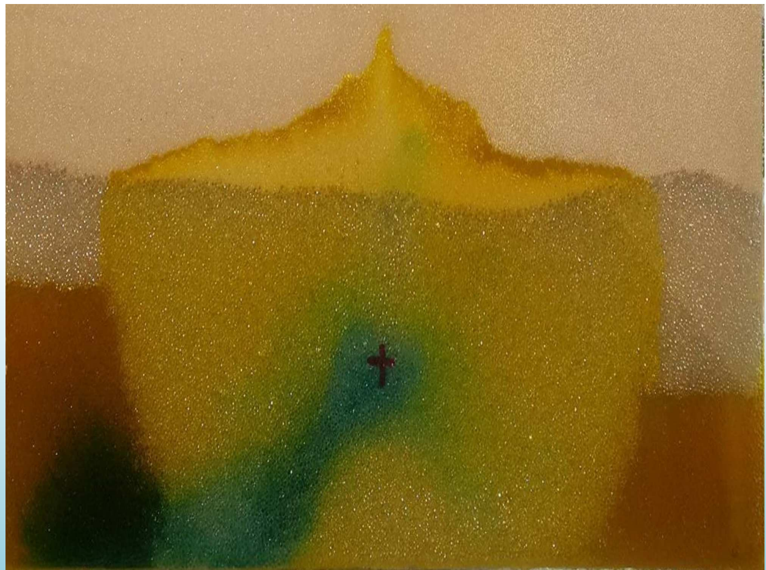
Learned lessons from field

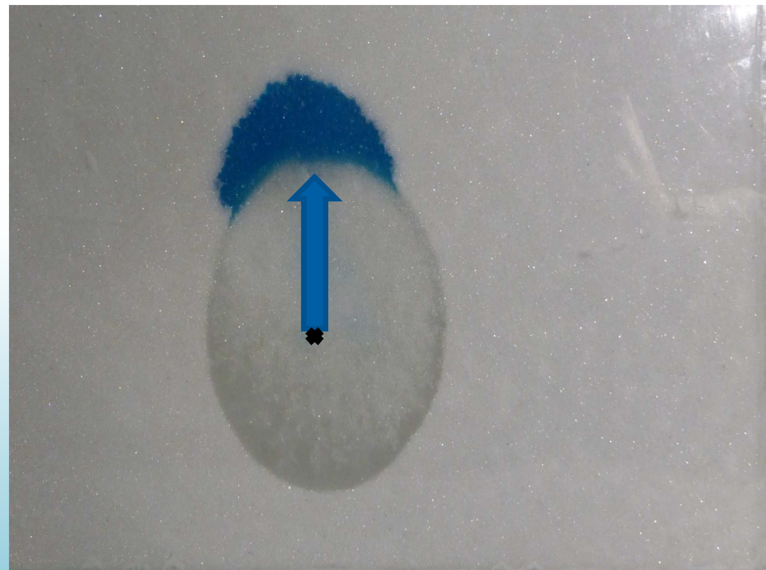
- Foam injection easy but slightly longer than solutions

- Transient regime to get strong foams longer with [VOCs]

+ Foam prevents release of toxic vapors during ISCO with Fenton

- P-controlled injection system to avoid fracturing when inject solutions





Related articles

Bouzid et al., 2017. J. Environ. Chem. Eng., 5, 6098

Maire et al., 2018. Chemosphere, 197, 661

Bouzid et al., 2018. Chemosphere, 210, 977

Bouzid et al,. 2019. Chemosphere, 233, 667

Bouzid et al,. 2019. J. Environ. Chem. Eng. https://doi.org/10.1016/j.jece.2019.103346

THANKS FOR YOUR ATTENTION

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