



Redonnons au sol sa valeur

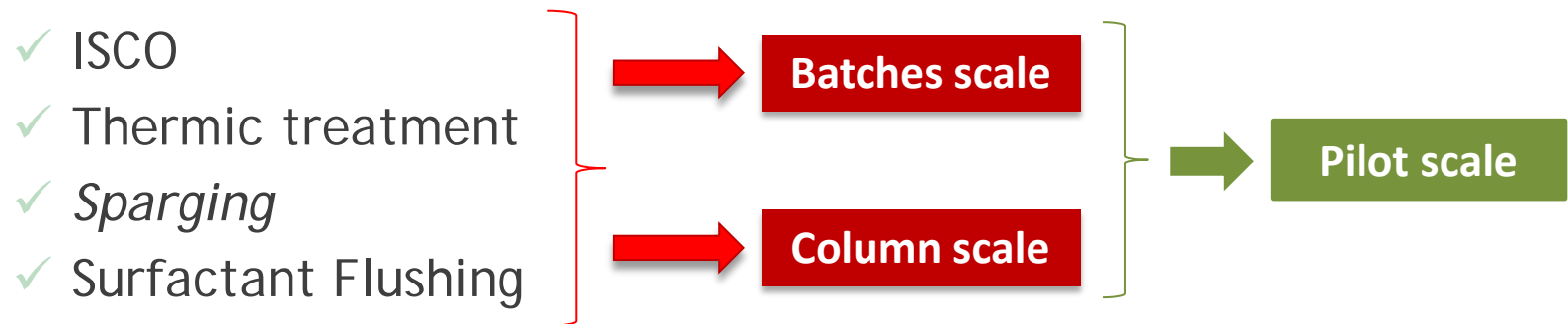
Comparison of in-Situ technics for soil remediation

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Fondation Innovasol

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Issues

Comparison of in situ technics to remediate soil contaminated by Diesel fuel mixture



Batches scale

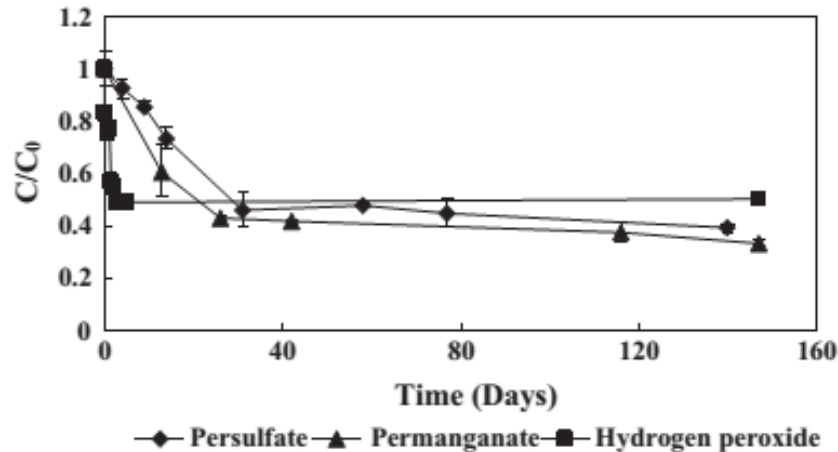


Fig. 3. Results of diesel oxidation by different oxidants (initial diesel concentration: 5000 mg kg⁻¹; persulfate concentration: 20%; permanganate concentration: 6%; hydrogen peroxide concentration: 20%).

Source : Yen *et al*, 2011

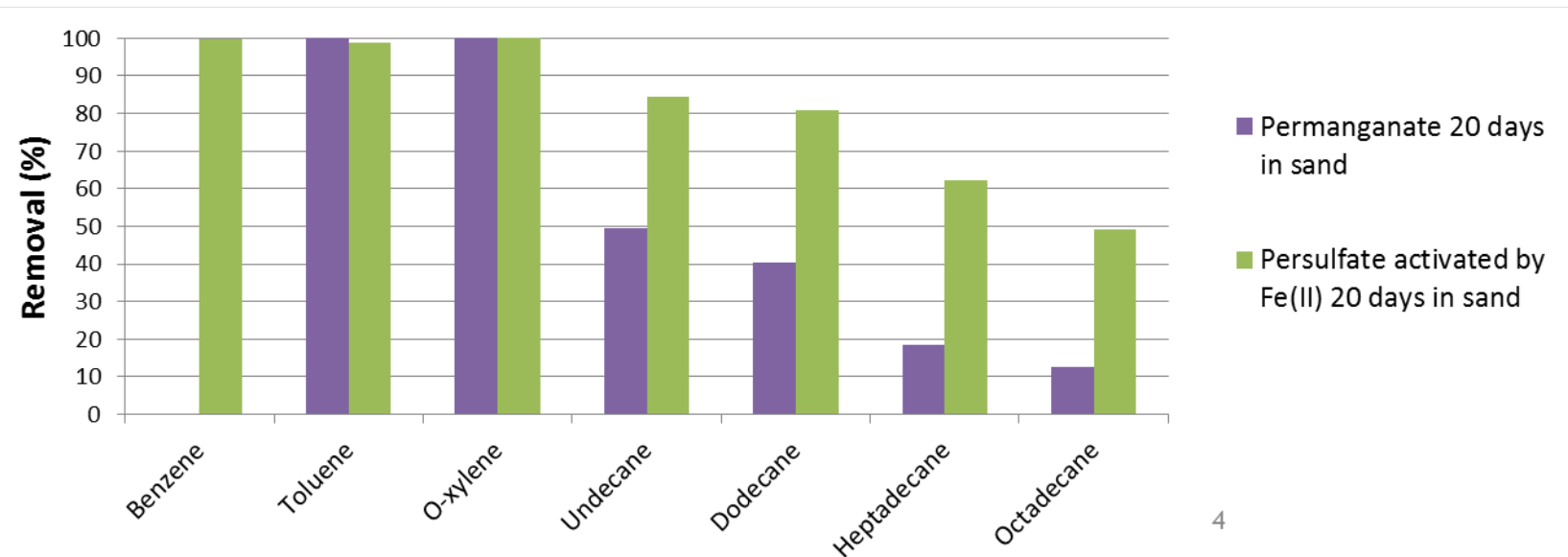
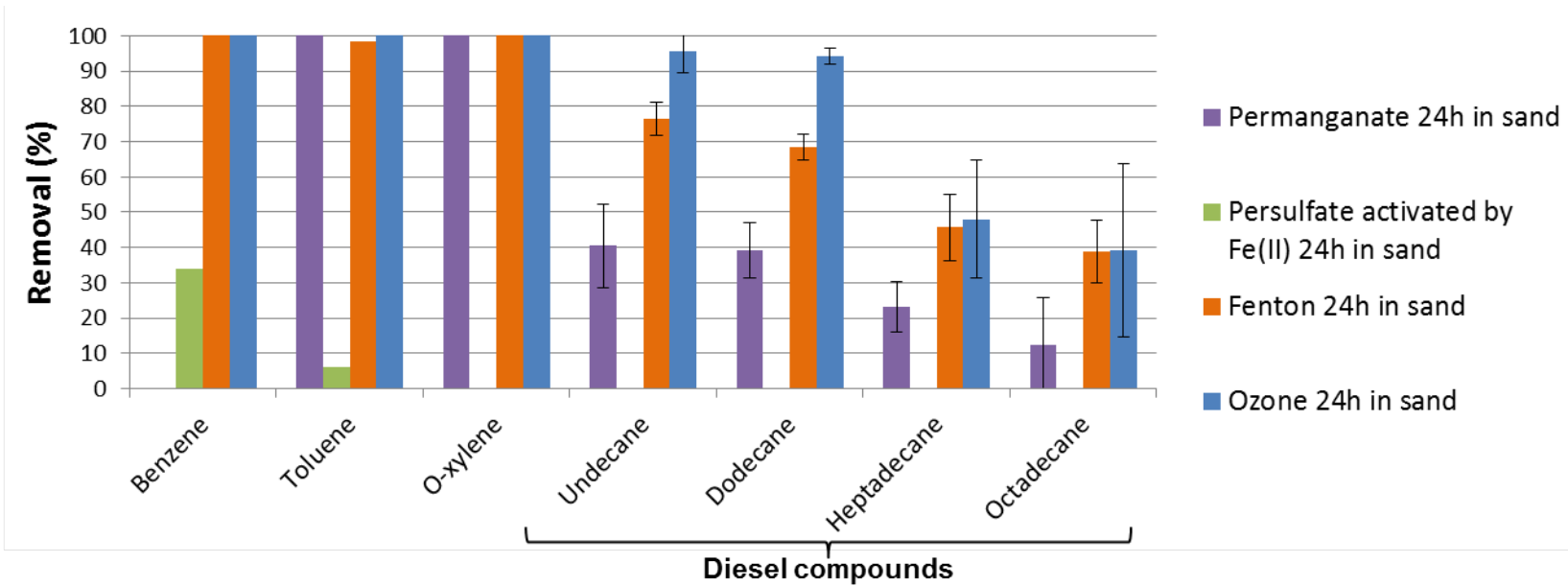
🌱 Low removal of Diesel fuel mixture by oxidants

- ✓ Influence of time treatment?
- ✓ Influence of organic matter (NOD)?

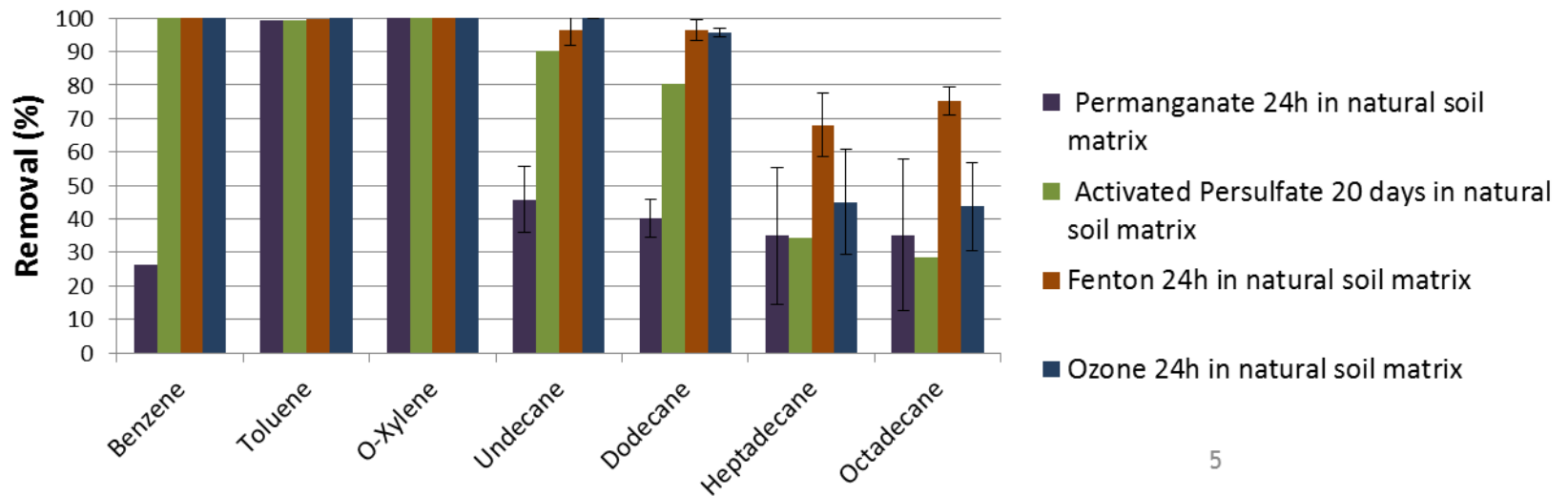
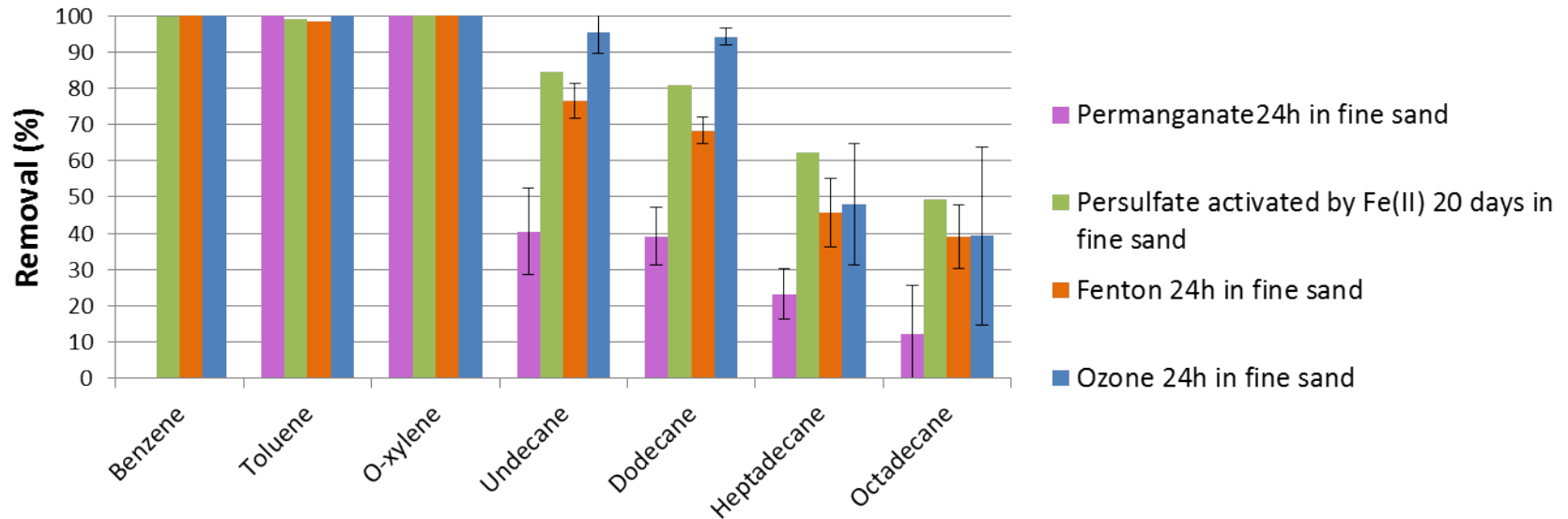


Realization of batches polluted by BTX and Diesel fuel mixture

Results on batches - Time influence



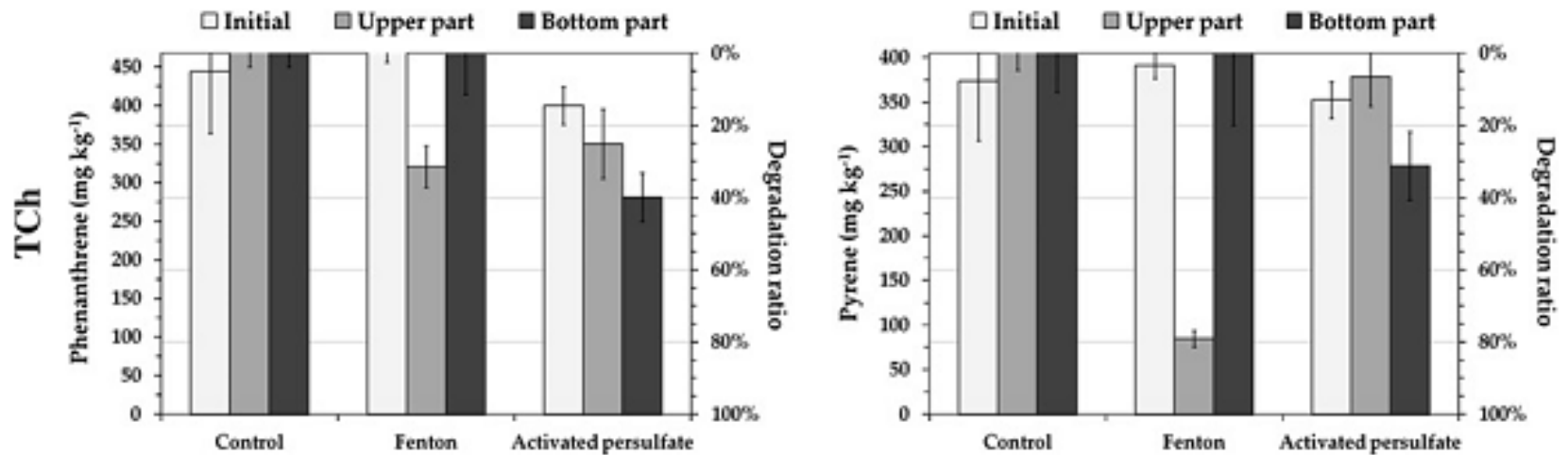
Results on Batches - Organic Matter influence



Conclusion - Batches Scale

- 🌱 Time influence on the effectiveness of activated persulfate by iron (II)
- 🌱 Increase of removal rate by NOD
- 🌱 Oxidants consumption by Alkanes

Columns scale



Source : Lemaire et al, 2013

🍌 Time spent into the column = 2h

✓ *Low efficiency of persulfate : influence of residence time?*

Columns scale

🍌 Column :

- ✓ *Pore Volume : 49,5 mL*
- ✓ *Water and pollutants saturated porosity (6%)*

🍌 Decane ($C_{10}H_{22}$)/Menthol ($C_{10}H_{20}O$)

- ✓ *Boiling point : 174,1° C and 212° C*
- ✓ *Water solubility : 0 and 400-500 mg/L*

🍌 Benzene, Toluene, o-Xylene (C_6H_6 , C_7H_8 , C_8H_{10})

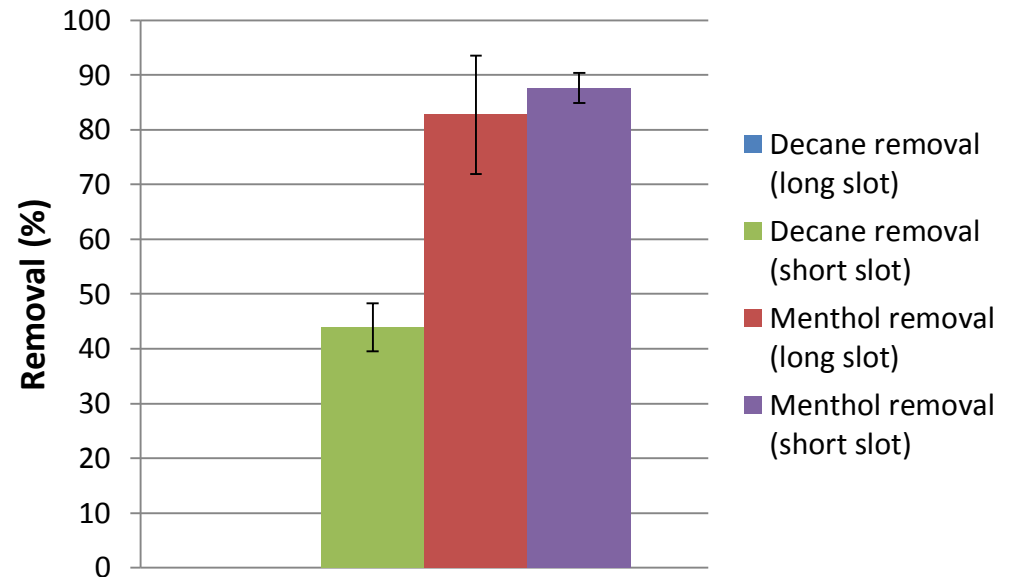
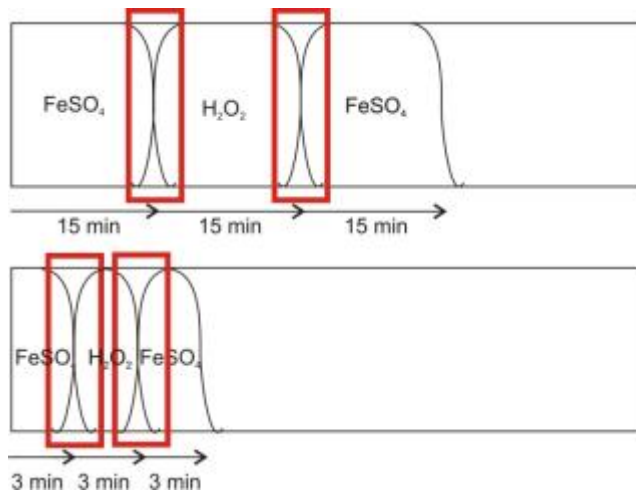
- ✓ *Boiling point: 80,1° C, 110,6° C, 144° C*
- ✓ *Water solubility : 1,79 g/L, 530 mg/L and 175 mg/L*



Results - colmuns scale

	Activated Persulfate Iron (II)	Fenton's reagent	Ozone	Sparging	Flushing by surfactant	Thermic treatment 70-80°C
Duration of treatment	2 months	7 days	7 days	7 days	20 days	7 days
Decane removal	56%	0%	49%	59%	0%	35%
Menthol removal	93%	83%	69%	53%	33,3%	14%
Source of efficiency	Optimal diffusion of the oxidant, low kinetic of the reaction	Strong oxidant efficient on soluble compounds	High solubility in water Better efficiency on soluble compounds			
Disadvantages		Injection in long slot Trial with short slot	Preferential passages of gaz	Preferential passages of gaz Solubility $O_2 < O_3$	No efficient, long treatment,	Boiling point of Decane and menthol to high

Oxidation of decane/Menthol mixture by Fenton's reagent



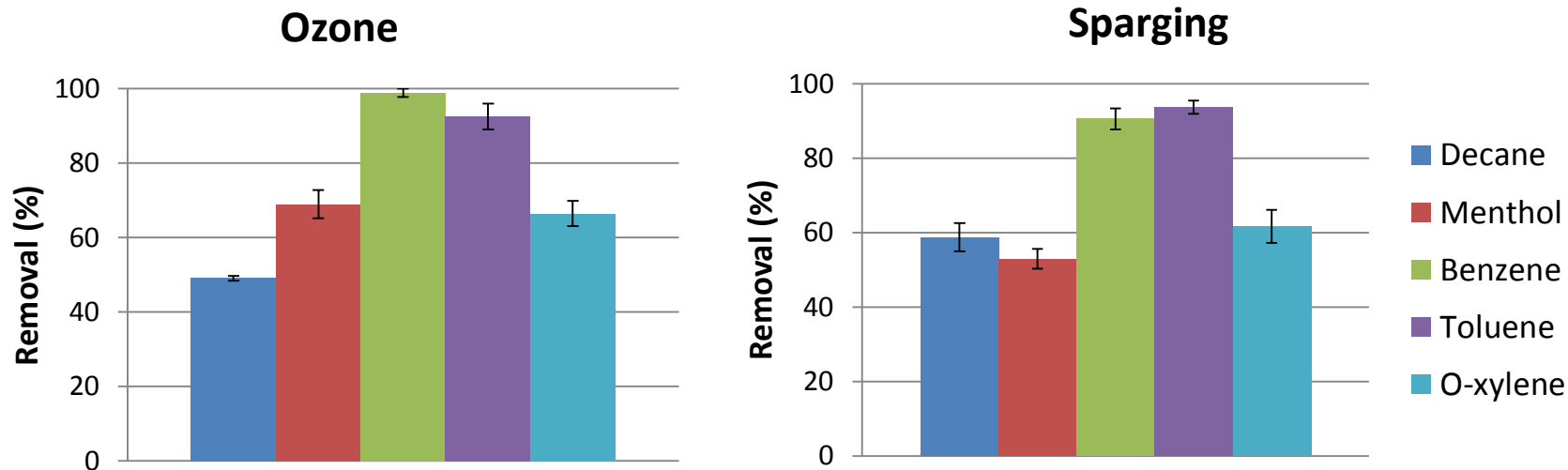
🍌 Optimal surface contact between hydrogen peroxyde and catalyser (iron II) = high production of Fenton's reagent

✓ *Increase of removal with short slot injection*

Results - colmuns scale

	Activated Persulfate Iron (II)	Fenton's reagent	Ozone	Sparging	Flushing by surfactant	Thermic treatment 70-80°C
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Disadvantages		Injection in long slot	Preferential passages of gaz	Preferential passages of gaz Solubility $O_2 < O_3$	No efficient, long treatment,	Boiling point of Decane and menthol too high
			Trial with more volatile compounds			

Ozone and Sparging treatments

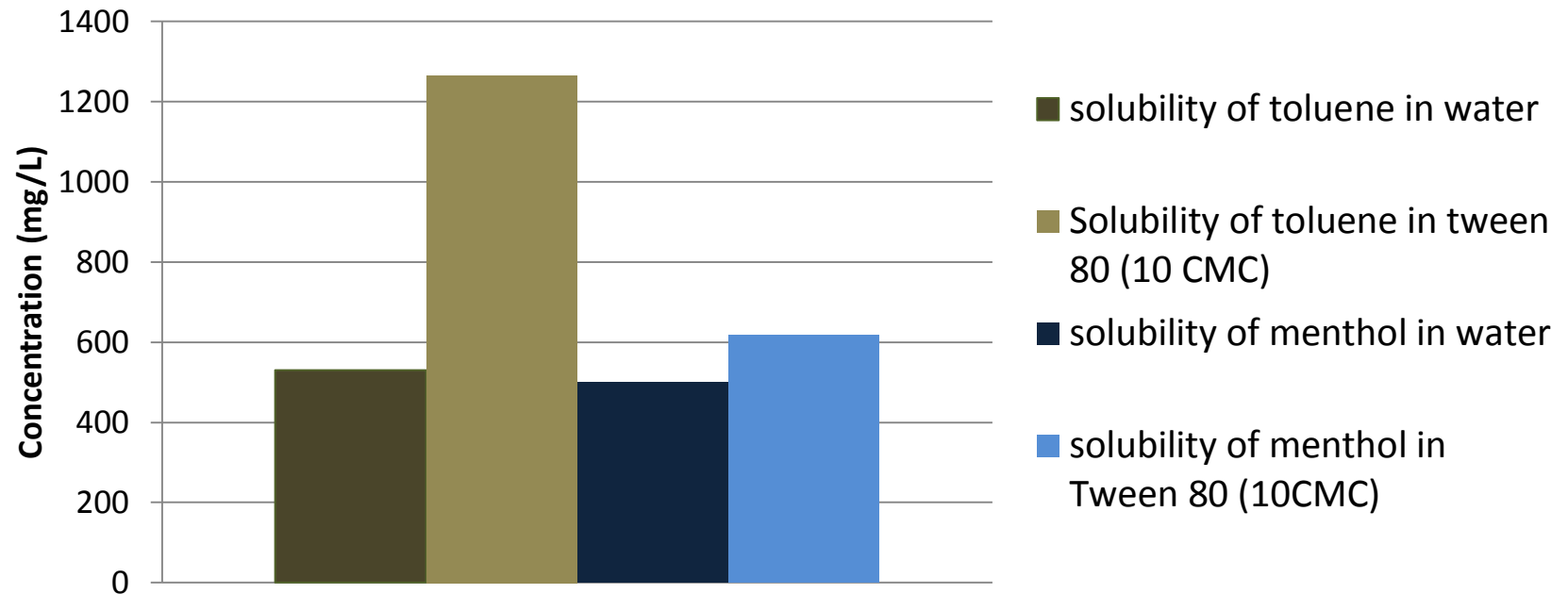


- 🌱 High elimination of benzene and toluene (volatil compounds)
- 🌱 Better efficiency of ozone than oxygen (high solubility of ozone in water)

Results - colmuns scale

	Activated Persulfate Iron (II)	Fenton's reagent	Ozone	Sparging	Flushing by Tween80	Thermic treatment 70-80°C
Duration of treatment	2 months	7 days	7 days	7 days	20 days	7 days
Decane removal	56%	0%	49%	59%	0%	35%
Menthol removal	93%	83%	69%	53%	33,3%	14%
Source of efficiency	Optimal diffusion of the oxidant, low kinetic of the reaction	Strong oxidant efficient on soluble compounds	High solubility in water Efficient on B,T compounds			
Disadvantages		Injection in long slot	Preferential passages of gaz	Preferential passages of gaz Solubility $O_2 < O_3$	No efficient, long treatment, Solubility power of Tween 80 on Toluene?	Boiling point of Decane and menthol too high

Solubilisation potential of Tween 80



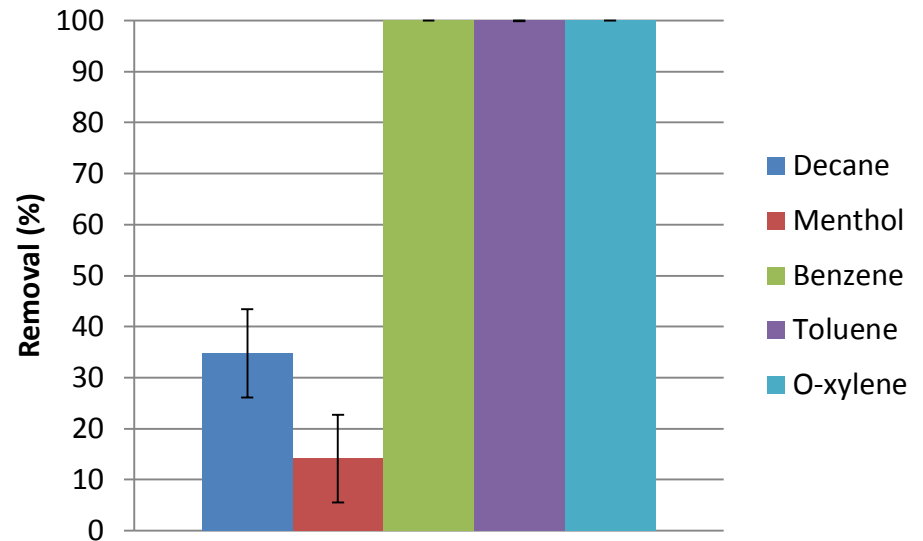
- 🌱 No efficiency of Tween 80 on Menthol
- 🌱 Increase of the solubility of Toluene in presence of Tween 80

Results - colmuns scale

	Activated Persulfate Iron (II)	Fenton's reagent	Ozone	Sparging	Flushing by Tween80	Thermic treatment 70-80°C
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Disadvantages		Injection in long slot	Preferential passages of gaz	Preferential passages of gaz Solubility $O_2 < O_3$	<div style="border: 1px solid green; padding: 5px;"> No efficient, long treatment, Efficient on Toluene </div>	<div style="border: 1px solid red; padding: 5px;"> Boiling point of Decane and menthol too high Trial with volatil compounds </div>

Thermic treatment on column

Pollutants used :
Benzene, Toluene and
O-xylene



Total degradation of BTX compounds after heating at 80° C

Conclusion – Columns scale

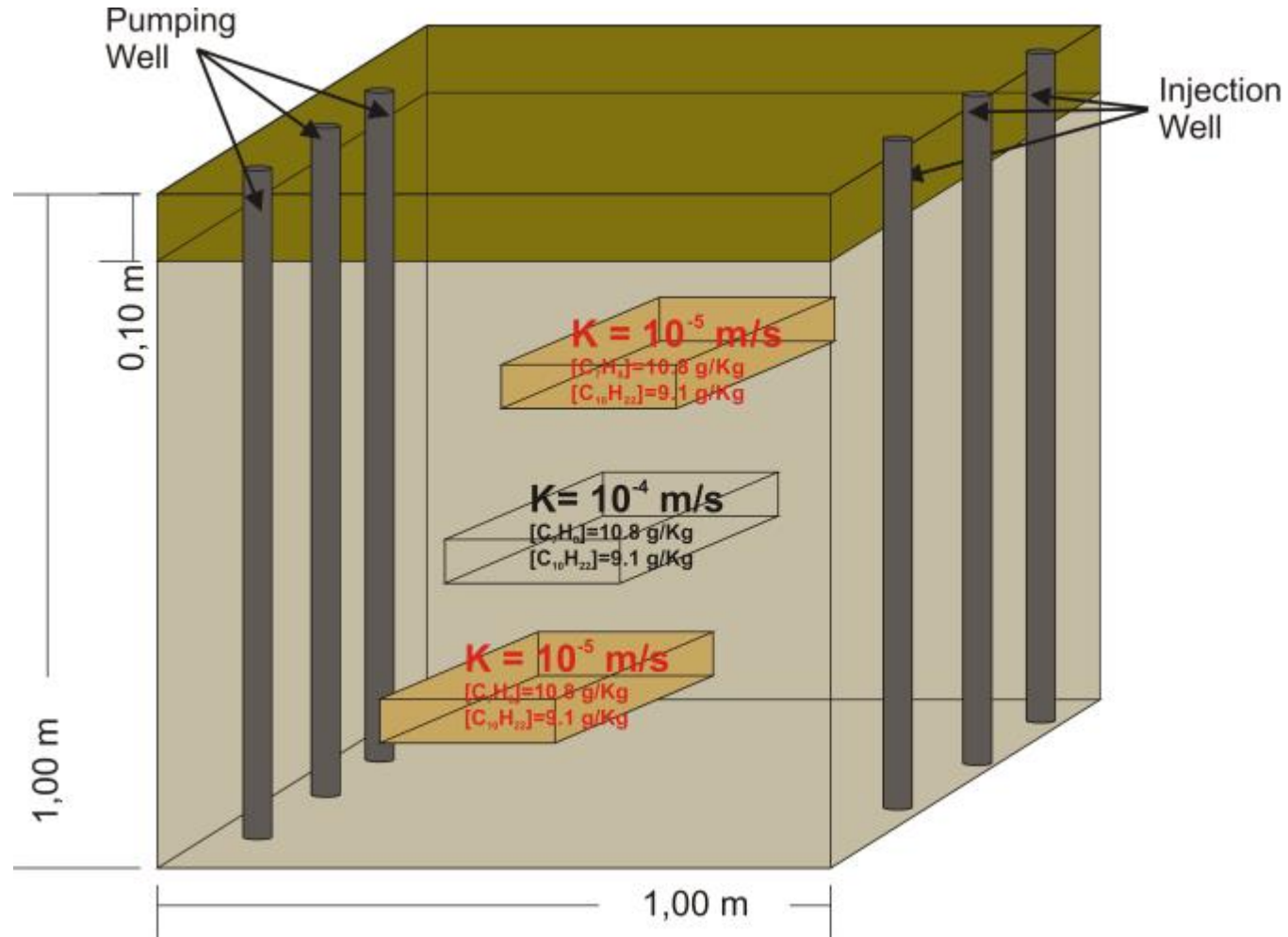
Liquid injection

- ✓ *Injection of liquid oxidants permitted a good diffusion through porous media*
- ✓ *Activated persulfate removed more menthol than Fenton's reagent due to persistence*
- ✓ *Tween 80 does not permit the solubilisation of Decane/Menthol mixture*

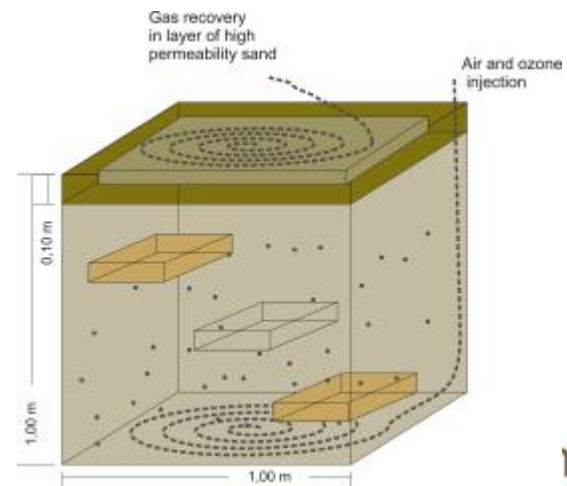
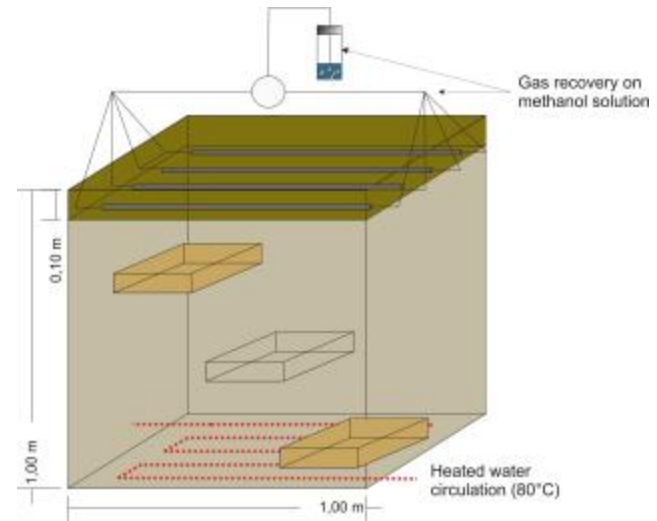
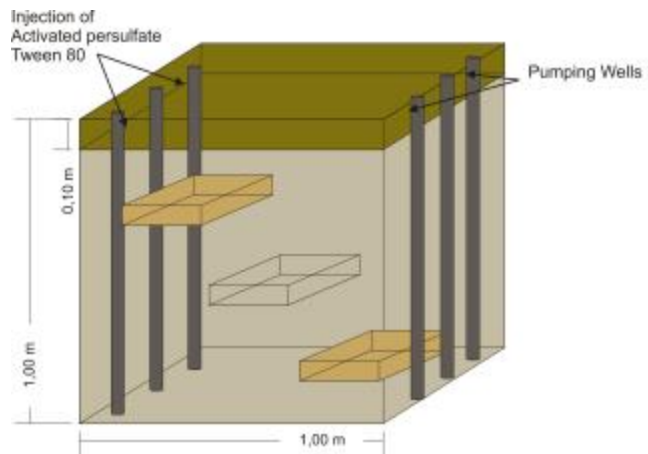
Gas Injection

- ✓ *Low removal of Decane/Menthol due to the presence of preferential passages*
- ✓ *High elimination of compounds with low boiling point*

PILOT 3D

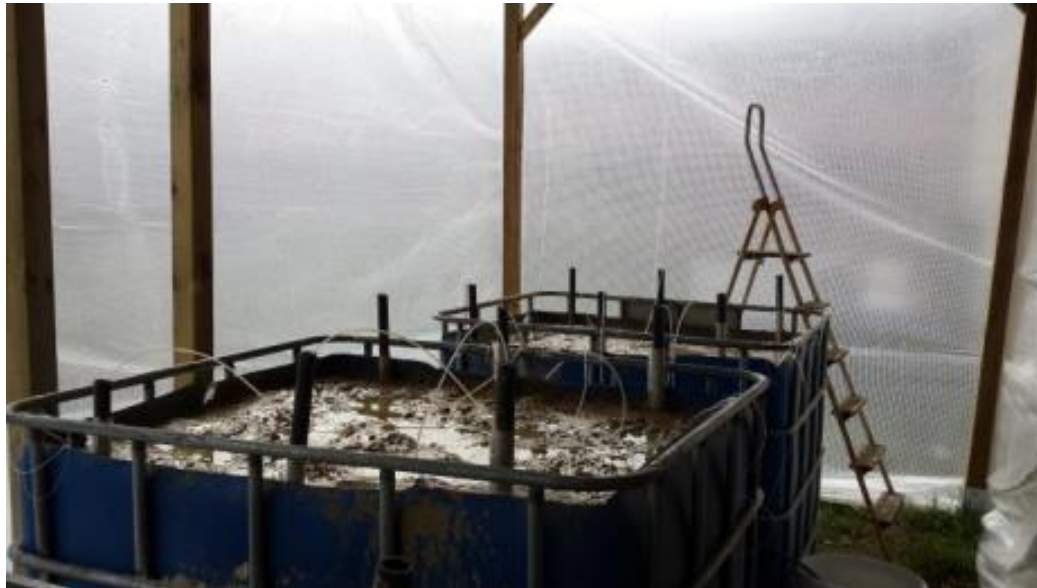


PILOT 3D - Treatments applied



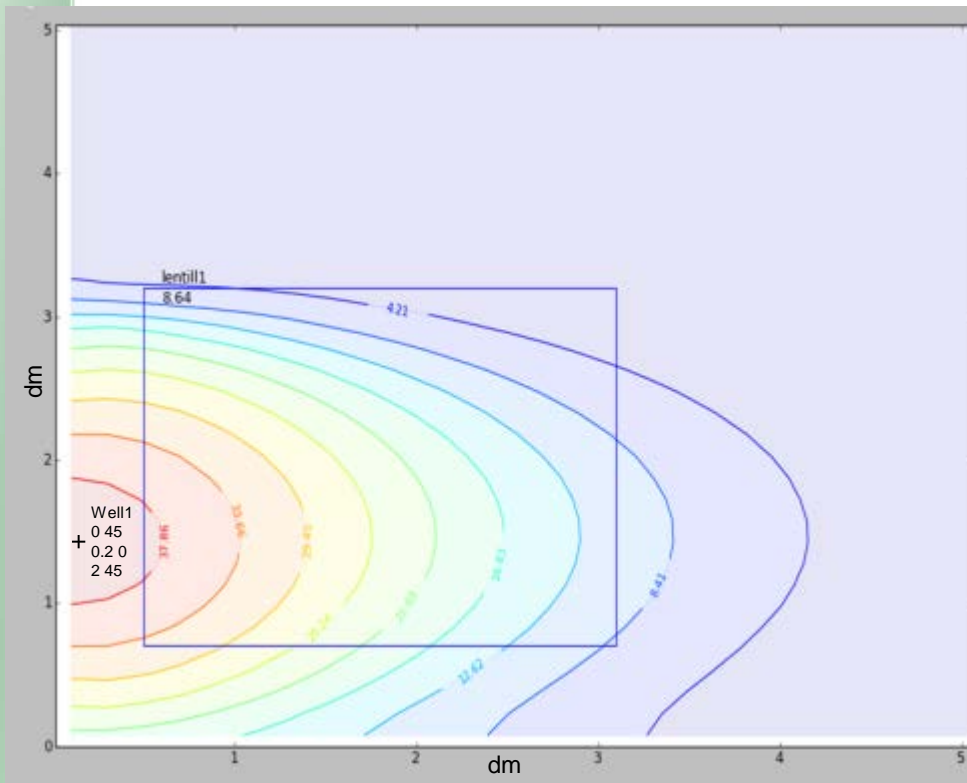
PILOT 3D - Water injection

- A long period of water injection was realised to eliminate toluene in the second lens (same permability as the sand around)
- Time of water injection : 2 months
- Flow : 45 L/day



Pilote 3D- Modelisation of injection of activated persulfate (ModFlow-Mt3DMS)

- 🌍 Plume of persulfate (high concentration) sink to the bottom of pilot due to the density of the oxidant solution



🌍 Model Conditions

- ✓ $[NaS_2O_8] = 50g/L$
- ✓ *Water injection in well 1 : one injection of 45 L every two days*



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Thank you for your attention

Cinétique et ratio polluants/oxydants

