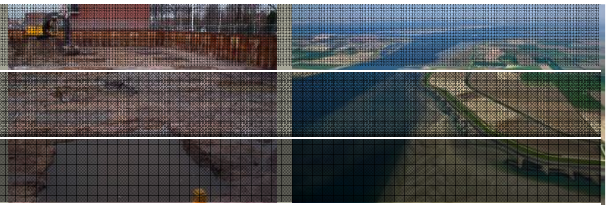
Deltares
Enabling Delta Life

Smart ISCO Application

Pauline van Gaans & co

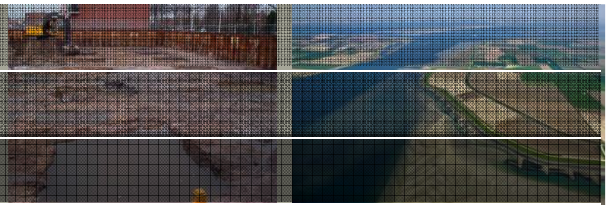
19 October 2011

Outline



- Perspectives
- Upsoil approaches
- From research to Smart ISCO application
- Conclusions/discussion

Perspectives



proposition 1:

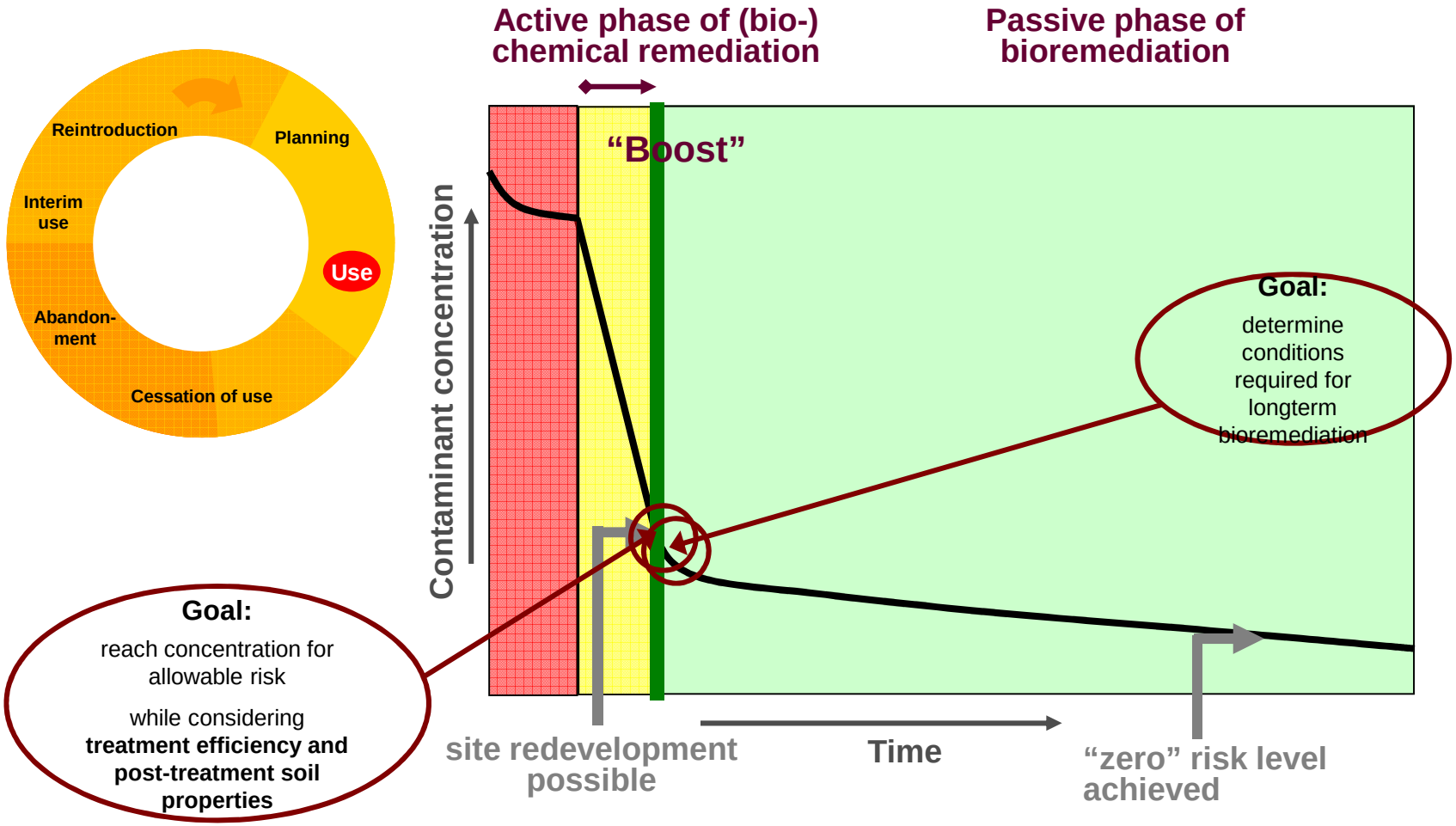
Regional management of contamination focussing on groundwater plume containment should consider source removal as part of the overall approach.

Perspectives

ISCO for source zone remediation

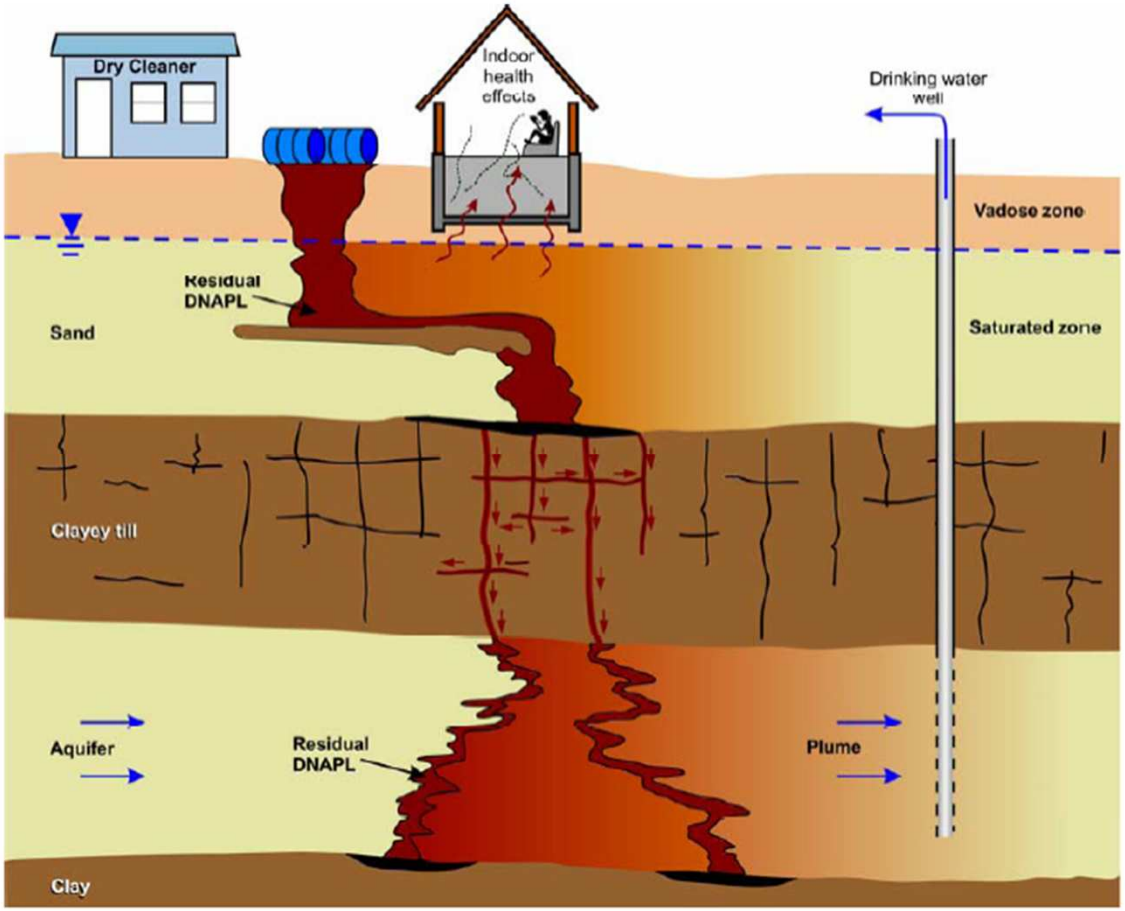
Technologies	Dimensions		
	cost	time	Sustain-ability
conventional:			
Excavation (**source** zone)	-	+	-
Pump-and-treat (**plume**)	-	-	-
***in-situ*:**			
Bioremediation (**plume**)	+	-	+
NA (**plume**, **source** by long term depletion)	+	-	+
ISCO & ISCR (**plume**, **source**)	-	+	-
UPSOIL:			
Smart coupling (**source** and **plume**)	+	+	+
Frontier technologies (**source** and **plume**)	+	+	+

Upsoil and the land use cycle



Perspectives

ISCO main issue: where is the source zone?



Perspectives

ISCO main issue: effectiveness and efficiency

potential of technology:

Contaminant Type	In-situ remediation technologies			
	Biological Oxidation	Chemical Oxidation	Biological Reduction	Chemical Reduction
Chlorinated Aliphatic Hydrocarbons (CAH)	Low	High	High	High
Total Petroleum Hydrocarbons (TPH)	High	High	No	No

Perspectives

ISCO main issue: effectiveness and efficiency

potential of technology:

Contaminant Type	In-situ remediation technologies			
	Biological Oxidation	Chemical Oxidation	Biological Reduction	Chemical Reduction
Chlorinated Aliphatic Hydrocarbons (CAH)	Low	High	High	High
Total Petroleum Hydrocarbons (TPH)	High	High	No	No

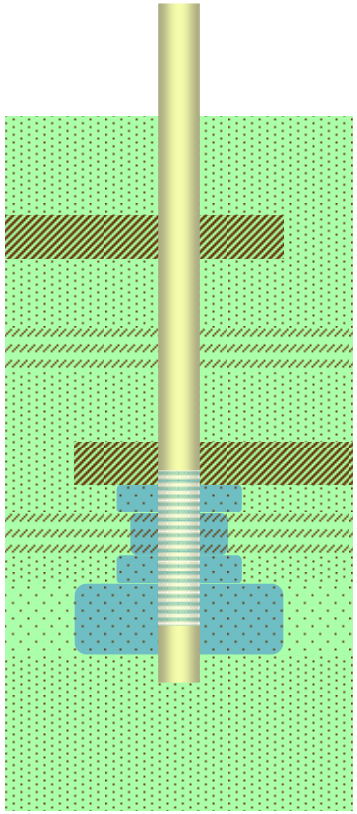
effectiveness: %Contaminant removed
eff/ectiveness: %Soil buffer retained
efficiency: [Contaminant removed]/[Oxidant applied]

Perspectives

ISCO main issue: effectiveness and efficiency

potential of technology:

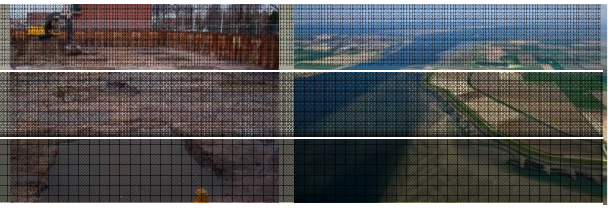
Contaminant Type	In-situ remediation technologies			
	Biological Oxidation	Chemical Oxidation	Biological Reduction	Chemical Reduction
Chlorinated Aliphatic Hydrocarbons (CAH)	Low	High	High	High
Total Petroleum Hydrocarbons (TPH)	High	High	No	No



effectiveness: %Contaminant removed
eff/ectiveness: %Soil buffer retained
efficiency: [Contaminant removed]/[Oxidant applied]

➔ soil *and* contaminant characteristics
➔ selectivity of oxidant

Upsoil approaches



Upsoil search to improve efficiency

- oxidant selectivity
- real-time feedback
- minimal ISCO, maximal BIO (Nora Sutton)
- better targetting of oxidant (Ole Stubdrup)

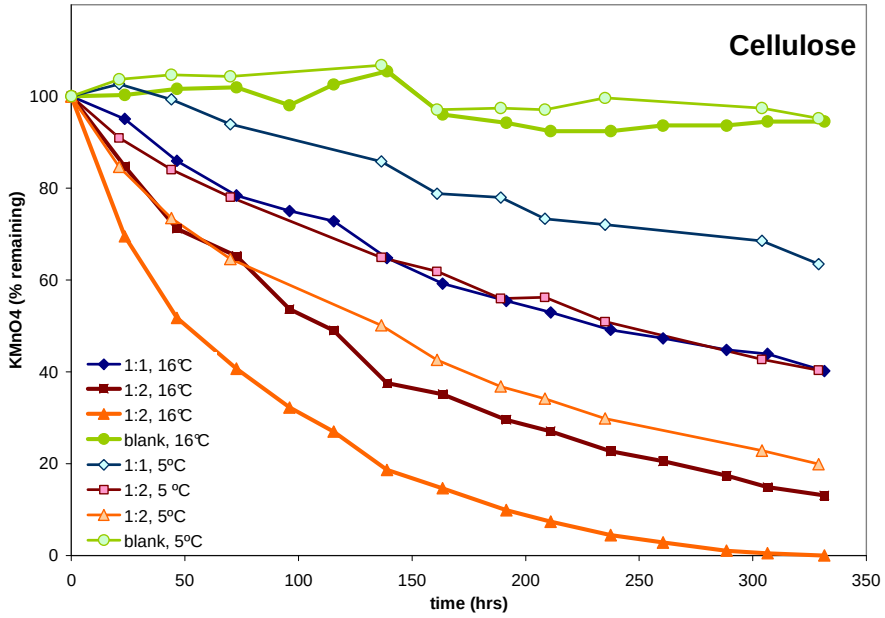
Oxidant selectivity and temperature

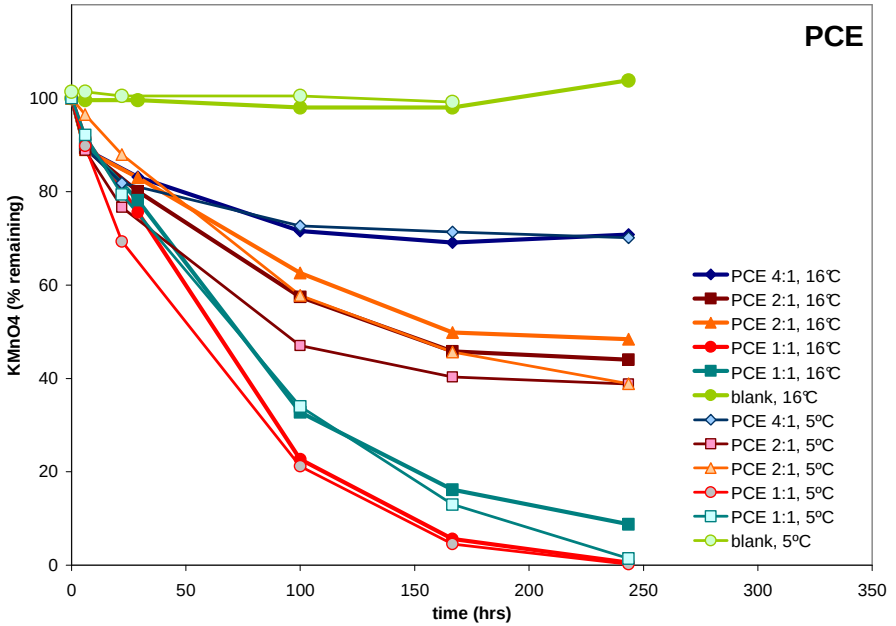
lab experimental approach

oxidant = permanganate

contaminant = tetracholorethylene (PCE) (as NAPL)

soil organic matter modelled by cellulose (as pure phase)

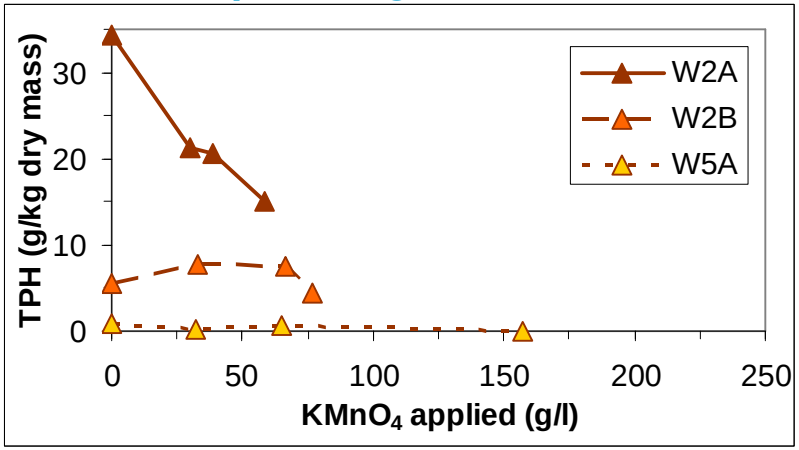


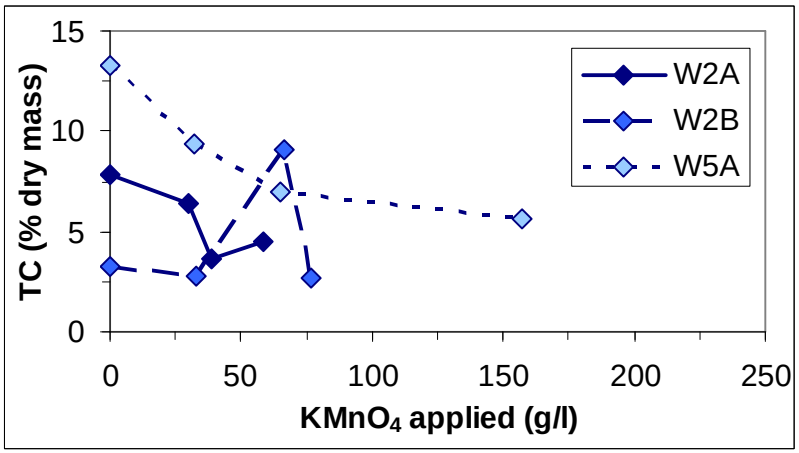


Upsoil approaches

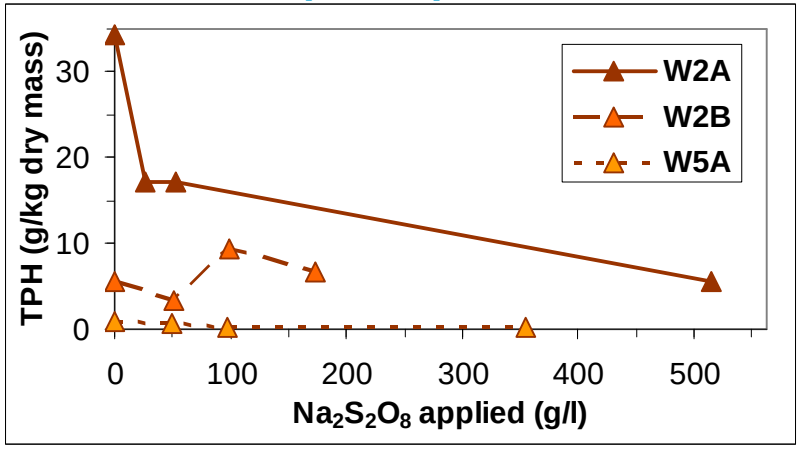
Oxidant selectivity (samples: diesel spill, anthropogenic fill)

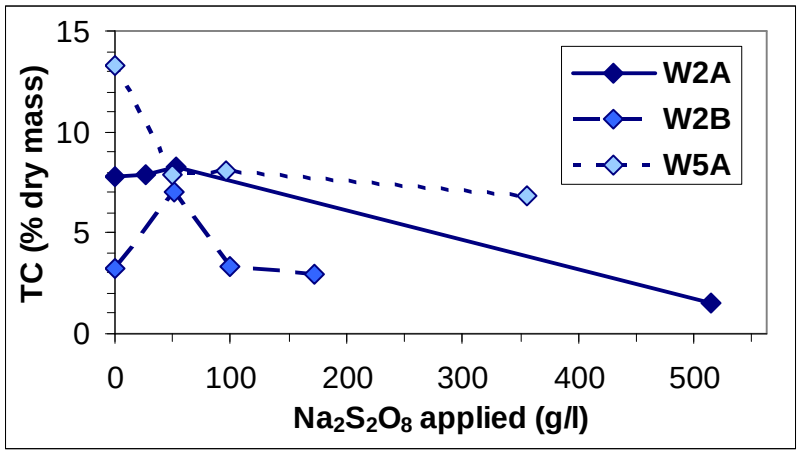
permanganate





persulphate



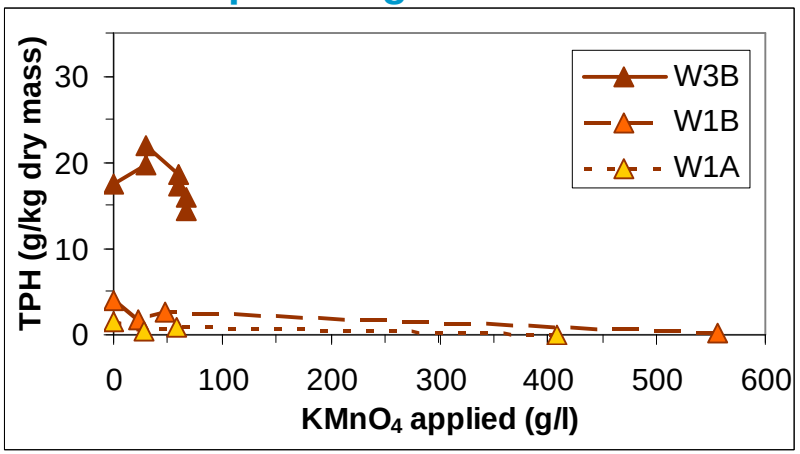


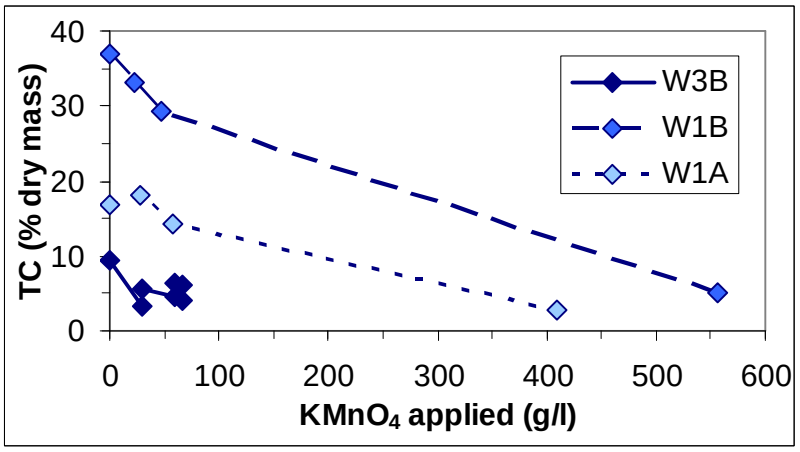
Upsoil approaches

Oxidant selectivity

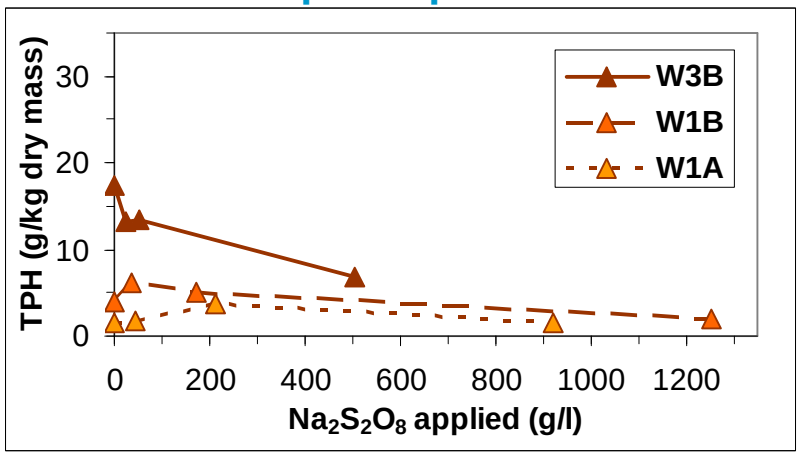
(samples: diesel spill, peat layer)

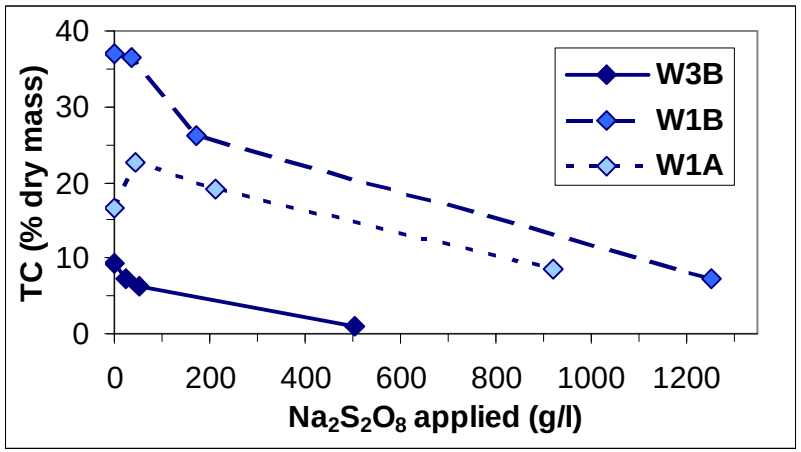
permanganate





persulphate





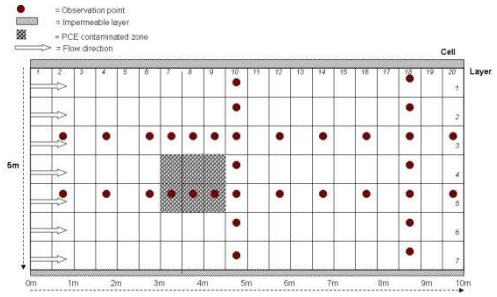
Oxidant selectivity, conclusions sofar

- use (low) temperature to advantage
- consider SOM *composition* in choice of oxidant
- consider longer term effect of oxidant on SOM
- ….
- ….

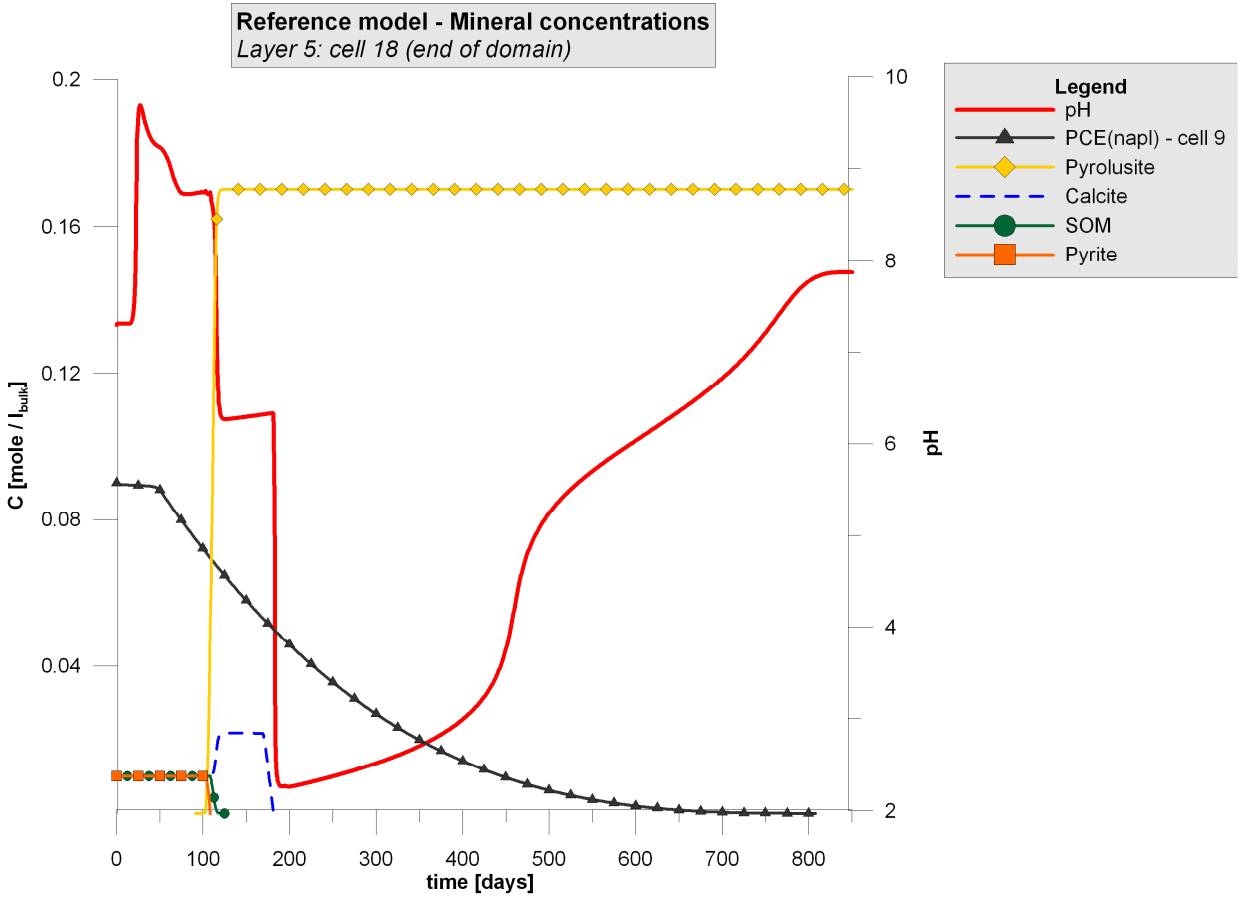
Upsoil approaches

Indicators for feedback

model approach

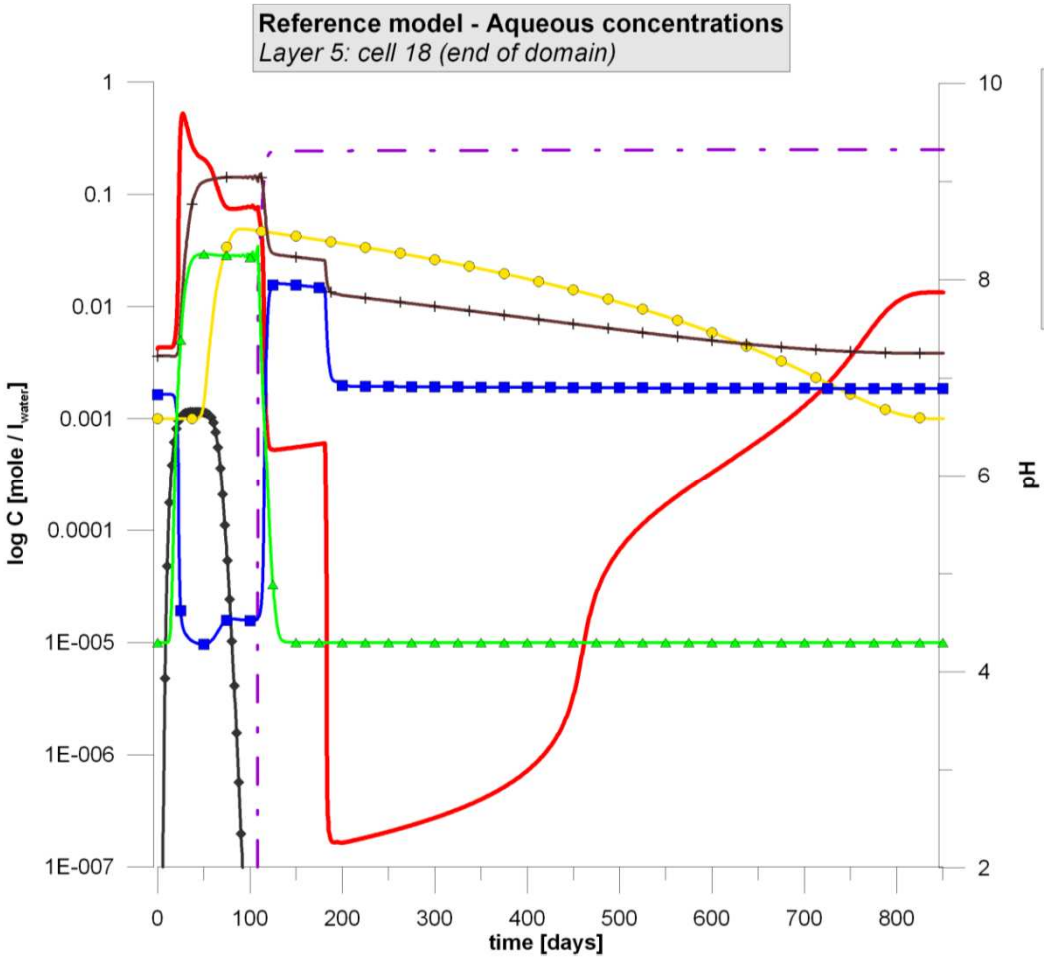


- ✓PCE residual NAPL
- ✓permanganate
- ✓sandy aquifer with
  - SOM
  - pyrite
  - calcite



Upsoil approaches

Indicators for feedback



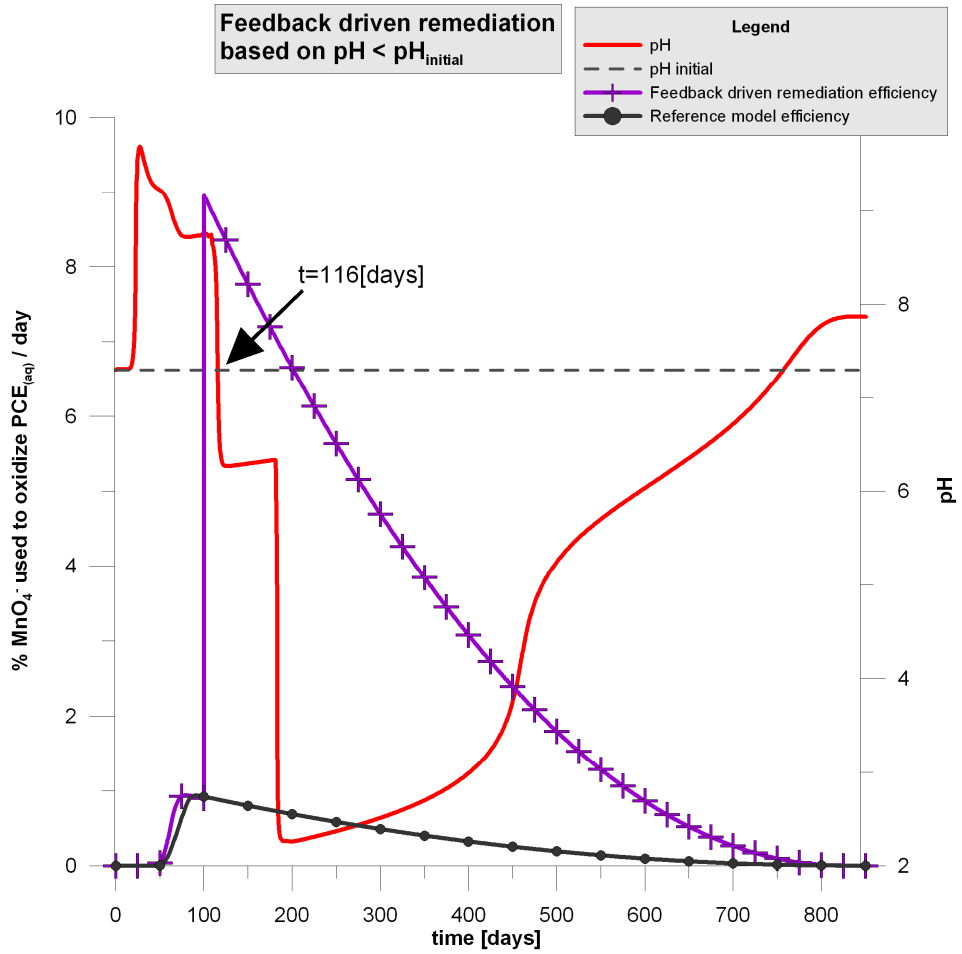
$$3C_2Cl_{4(aq)} + 4MnO_4^- + 4H_2O \rightarrow 6CO_{2(aq)} + 12Cl^- + 4MnO_{2(s)} + 8H^+$$

$$CH_2O + 12H^+ + 12MnO_4^- \rightarrow 12MnO_{2(s)} + 9CO_{2(aq)}$$

$$FeS_{2(s)} + H^+ + 5MnO_4^- \rightarrow 5MnO_{2(s)} + 2SO_4^{2-} + FeOOH_{(s)}$$

Upsoil approaches

Feedback improved efficiency



Upsoil approaches

Feedback driven, conclusions sofar

- case of PCE: pH good indicator
- other potential indicators: Cl, SO_4
- ….

- **zero PCE concentration** in downstream observation well
  not a good indicator!

- efficiency can be increased

  Adjustable oxidant injection characteristics:
  - Concentration
  - Injection rate
  - Location of injection

From lab research to field application

model

"known" system
- composition
- flow regime
- chemical processes
- complete observation

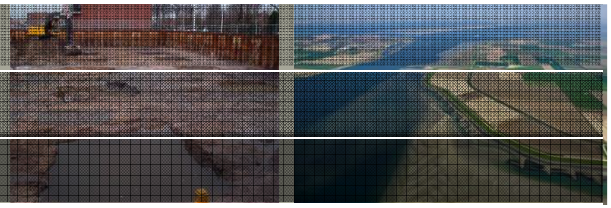
lab (batch experiment)

- (partly)known systems
  - composition
  - chemical processes
- high water to soil/NAPL ratios
  - optimal mixing
  - optimal contact surface
- high oxidant concentrations possible
  - prolonged reaction, simulating multiple injections with time

field

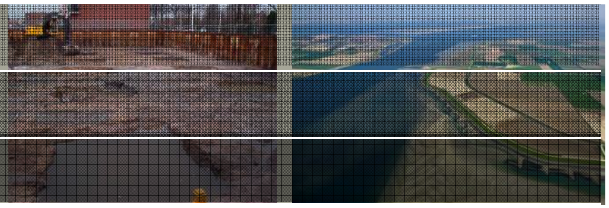
- black box
- many other processes going on as well
  - fluid injection → displacement of groundwater & dissolved contaminant
  - multiple well-field → enhanced local flow & dispersion
  - temp increase → enhanced volatilization
  - gas production (bubbles) → volatilization, stripping, enhanced dispersion
  - oxidation of soil matrix → desorption of contaminant (if anti-selective)
  - high residual NAPL saturation → low effective permeability!
  - solubilization (=from resiudal to dissolved)
  - mobilization (=from residual to pool)
- black box

Conclusions



- **ISCO methods fill a niche in soil remediation for source removal**
- **Current ISCO applications can be improved considering dimensions of cost and sustainability**
- **Bridging of research findings and field experience important**

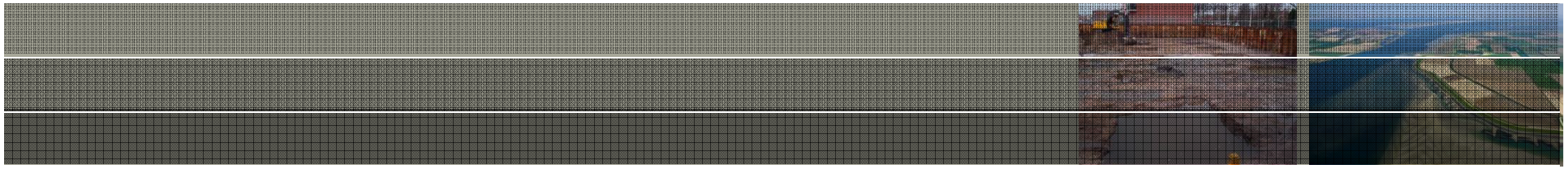
Discussion



proposition 2:

To get SMARTer, we need to learn from experience.

Regional management of subsurface contamination could foster research involvement in modelling and monitoring designs for ISCO.



Thanks for your attention