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Considerations in selecting in situ remediation technologies: Cost, Time, Sustainability

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Bucharest, 2 July 2012

National Workshop: Rehabilitation of contaminated soil and sites

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SEVENTH FRAMEWORK PROGRAMME

Presentation outline

- General introduction
- Upsoil Smart coupling
- Field sites
- Laboratory tests
- Result examples
- Conclusions

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Result examples

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Soil contamination & remediation

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conventional ex-situ soil remediation:

- site disturbance, nuisance
- disorder of soil functions
- high costs (transport & ex-situ treatment)
+ fast (months to year)
+ proven technology, certain result

costs | time | sustainable

in-situ natural/enhanced attenuation

+ limited disturbance, nuisance
+ making use of soil function
+ low costs (monitoring)
- slow (years to decades)
- knowledge intensive, uncertain result

costs | time | sustainable

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General introduction

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Soil contamination & remediation

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in-situ chemical soil remediation:

- moderate site disturbance, nuisance
- temporal disorder of soil functions
- high costs (chemicals, injection wells)
+ fast (months to year)
+ knowledge intensive certain result?

costs | time | sustainable

in-situ natural/enhanced attenuation

+ limited disturbance, nuisance
+ making use of soil function
+ low costs (monitoring)
- slow (years to decades)
- knowledge intensive, uncertain result

costs | time | sustainable

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General introduction

Sustainability

- **here focus on:**
  - **cost-efficient use of chemicals**
  - **natural soil functions**
- in wider context also includes:
  - overall resource & energy efficiency,
  - CO_2 footprint,
  - overall environmental impact
  - societal impacts
  - ………..

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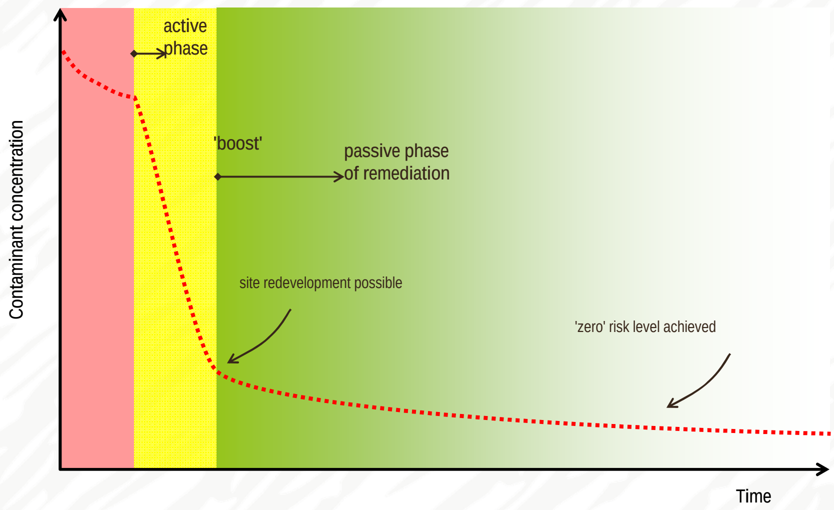
General introduction

Upsoil: smart coupling



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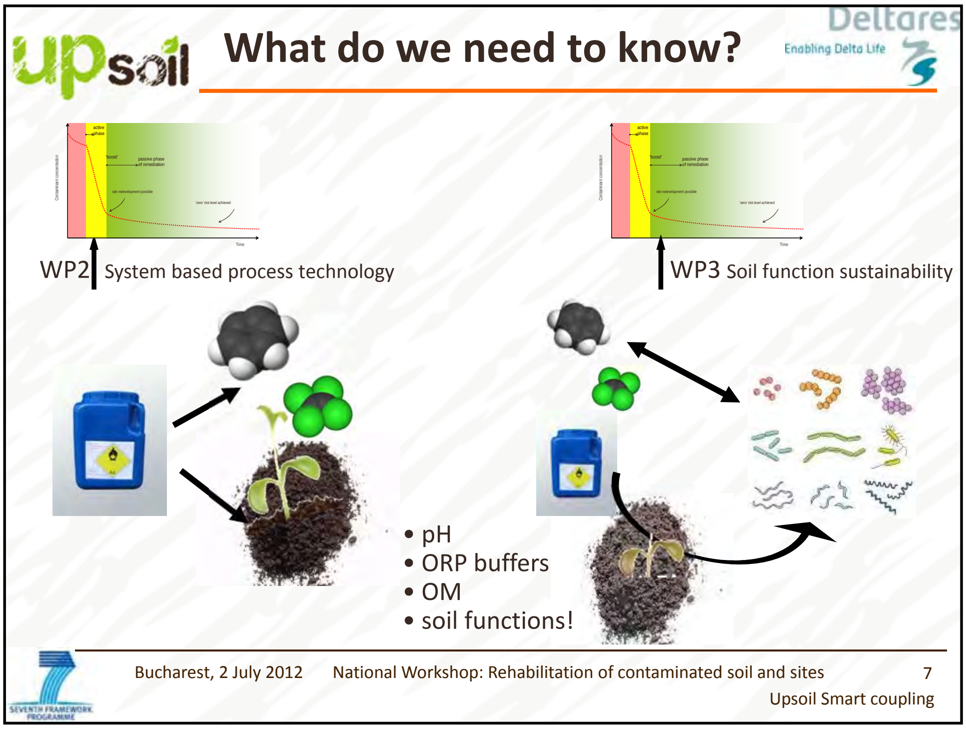
Upsoil Smart coupling



Potential improvements

- **costs:**
  - minimise active treatment:
    - less chemicals needed
    - faster re-use of site
  - minimise effect on soil:
    - less chemicals needed & faster
    - less soil improvement needed
- **time:**
  - minimise active treatment and effect on soil:
    - where needed, faster re-use of site
    - where time allows, use natural system to its maximum
  - more detailed pre-investigation:
    - less unpleasant surprises
- **sustainability:**
  - minimise use of external resources
  - minimise effect on soil: soil functions maintained

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Upsoil Smart coupling

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WP2 Field sites

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Field sites

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Design of laboratory tests

- Wegliniec
  - soil types: anthropogenic fill, peat, clay, sand
  - contaminant grades: clean, 'plume', 'source'
  - oxidants: permanganate, persulphate, (percarbonate), Fenton's
- Brückl
  - sediment types: above & below groundwater
  - contaminant grades: clean, 'dissolved', 'residual'
  - oxidants: permanganate, persulphate, Fenton's
  - reductants: zero-valent iron, lactate
- Antwerp
  - reductants: zero-valent iron, lactate

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Laboratory tests

Lab-test partners

Ecoind:
- oxidation, Wegliniec pure product

Dekonta:
- oxidation, Wegliniec source zone samples

Dekonta + Ecoind:
- oxidation, Brückl spiked samples (residual NAPL)

Deltares:
- oxidation, Wegliniec clean & plume samples
- oxidation, Brückl pure product, clean soil and spiked soil (dissolved)

WUR
- Fenton's oxidation, Wegliniec and Brückl

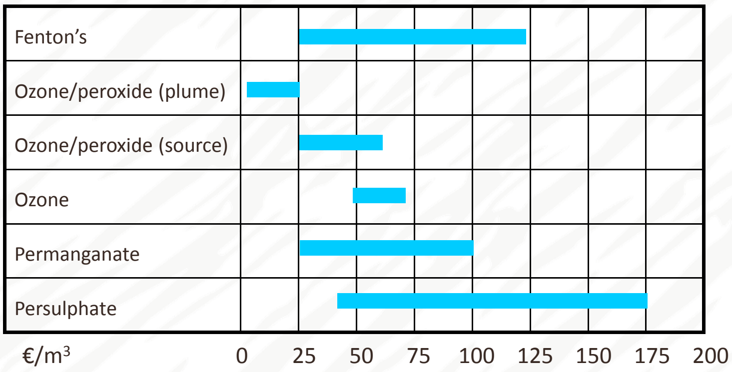
VITO
- (bio)chemical reduction, Antwerp & Brückl

Considerations

- overall costs
- contaminant
  - degradability by reagent
  - mode of appearance
  - concentration level
- reagent
  - applicable for volume approach
  - applicable for linear approach
- soil/subsurface characteristics
  - NOD, potential effect of contaminant degradation on NOD

flow charts
matrix-tables
rules of thumb
soil test protocols

Treatment ←→ Costs



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Result examples

Concentration ←→ Treatment

Contaminant concentration	(Modified) Fenton's	Permanganate	Persulphate	Ozone & ozone/peroxide
Chlorinated Aliphatic Hydrocarbons (CAH)				
Very low	No	Fair	Fair	Excellent
Low	Fair	Excellent	Good	Excellent
Moderate	Excellent	Excellent	Excellent	Excellent
High	Excellent	Excellent	Excellent	Good
Very high	Good	Good	Good	Fair
Total Petroleum Hydrocarbons (TPH)				
Very low	Good	Fair	Good	Excellent
Low	Excellent	Excellent	Excellent	Excellent
Moderate	Excellent	Excellent	Good	Excellent
High	Excellent	Good	Fair - Excellent	Fair
Very high	Good	Good	Fair - Good	Poor

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Result examples

Contaminant type ←→ Treatment

Contaminant concentration	Fenton's	(Modified)	Permanganate	Persulphate	Ozone & ozone/peroxide
Chlorinated Aliphatic Hydrocarbons (CAH)					
Perchloroethene	Excellent		Excellent	Excellent	Excellent
Trichloroethene	Excellent		Excellent	Excellent	Excellent
Dichloroethenes	Excellent		Excellent	Excellent	Excellent
Vinyl chloride	Excellent		Excellent	Excellent	Excellent
Tetrachloroethanes	Poor	Fair	No	Fair	Fair
Trichloroethanes	Poor	Fair	No	Poor - Good*	Good
Dichloroethanes	Fair	Good	No	Poor - Good*	Good
Chloroethane	Fair	Good	No	Poor - Good*	Good
Carbon tetrachloride	Poor	Excell.	No	No - Fair Exc.*	No
Chloroform	Poor	Good	No	No - Good*	Poor
Total Petroleum Hydrocarbons (TPH)					
Light fuels	Good		Fair	Good - Excell.*	Good
Heavy fuels	Fair		Poor	Poor - Good*	Fair
Creosote, tar	Good		Fair	Poor - Good*	Good
2&3 ring PAHs	Good		Fair	Poor - Good*	Good
4,5&6 ring PAHs	Fair		No	No- Fair*	Poor
PCBs	Fair		No	No - Good*	No
Benzene	Excellent		No	Excellent	Excellent
ETX	Excellent		Excellent	Excellent	Excellent
MTBE	Excellent		Poor	Excellent	Good
Tert-butyl ether	Fair		No	Poor - Good*	Fair

* depending on possibility of activation (specifically peroxide or thermal)

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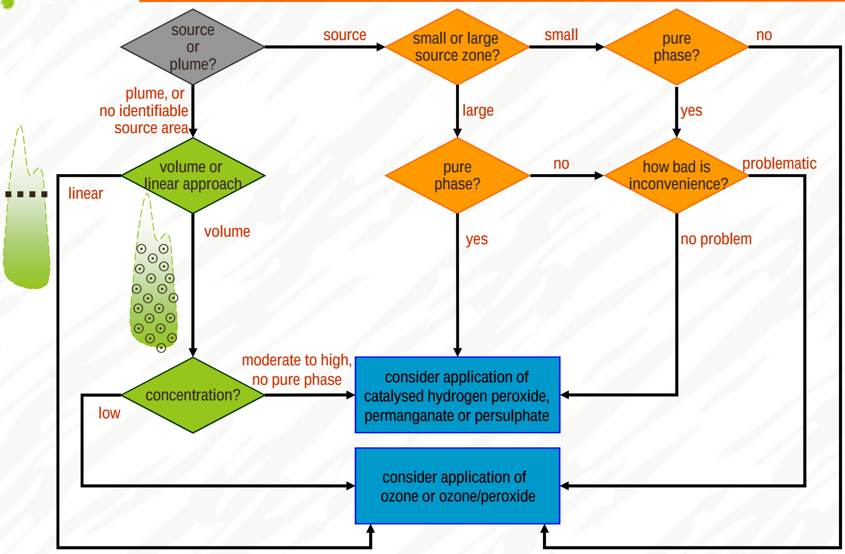
Result examples

Mode of appearance ←→ Treatment



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Result examples

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Examples of Rules

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Chemical oxidation becomes less sustainable at low contaminant concentrations, high amounts of reactive soil components, or relatively high soil reaction rates

***

Prior to the full scale application of a selected chemical oxidation technology, laboratory and field pilot tests should always be conducted to determine the remediation effectiveness and efficiency

***

When selecting a combination or train of remediation technologies one should take into account the possible formation of an additional buffer capacity formed by the technology first implemented (for example the formation of Mn-oxides as a result of ISCO using permanganate)

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Result examples

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Soil geochemical conditions

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Medium	Parameter	Potential effect on remediation treatments
Solid soil	Carbonate mineral content	Buffer against acidification e.g. optimal reaction pH<4 for Fenton's reagens may not be achievable
	Redox sensitive elements (Fe, As, Cr,..)	Treatment may alter redox state and mobility, consumption of reagent and risk of unwanted concentrations in remediation area
	Soil organic matter content	Consumes oxidant, effects dose and deliverability
	Clay content	Consumes oxidant, effects dose and deliverability
Ground water or injection fluid	Temperature	Can effect reaction rates (soil and contaminant differently)
	pH	Can effect reaction chemistry e.g. Fenton's reagens and certain activated persulfate applications
	Dissolved oxygen / ORP	Indicative for redox conditions and mineral assemblage in remediation area
	Alkalinity	Can effect reaction chemistry e.g. CO_3^{2-} acts as a scavenger for certain radicals
	Anions (F^-, Cl^-, NO_3^-, HPO_4^{2-} , SO_4^{2-}, ...)	Can effect reaction chemistry as these anions act as a scavenger for certain radicals e.g. ·OH-radicals
	Cations (Fe^{2+}, Mn^{2+}, ...)	Can effect reaction chemistry as these cations can act as potential activators

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Result examples

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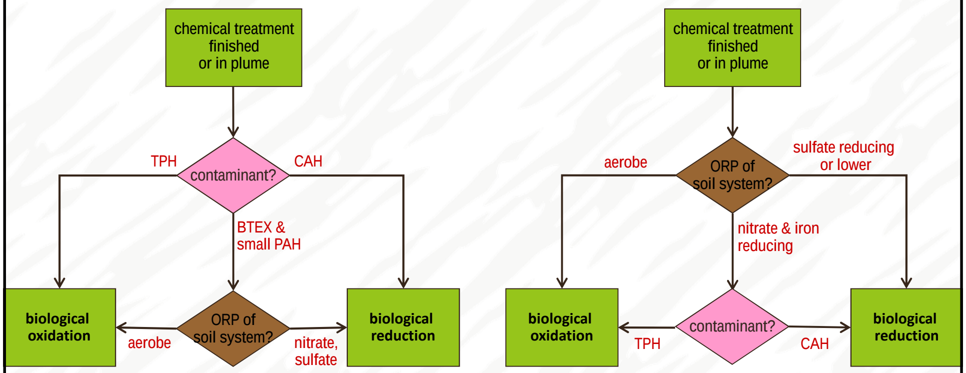
Potential for coupling with biodegradation

Contaminant perspective first

Soil conditions perspective first



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Conclusions

- **Chemical treatments fill a niche in soil remediation, specifically for an active phase of source removal. Current applications can be improved considering the dimensions of cost, time, and sustainability.**
- **Considerations in the selection of the optimal chemical treatment need to adress contaminant-reagent-soil in an integrated manner.**
- **The choice for an optimal chemical treatment also depends on whether or not a subsequent bioremediation phase is foreseen/needed.**
- **Investments in more extensive pre-treatment research outweigh the risk of unexpected high costs in the treatment phase.**


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for your attention