Implementation of ISCO in soil remediation: lessons learned

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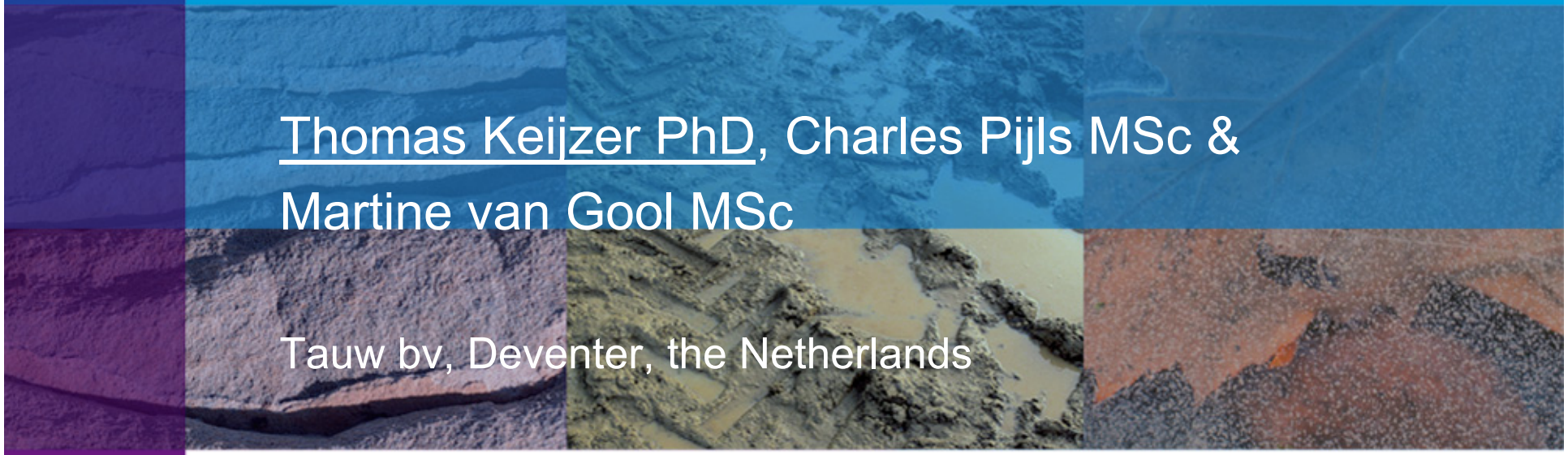

Tauw

Tauw?

- Consultancy firm with offices in six European countries including France (*Tauw Environnement* in Dijon, Lyon, Douai & Paris)
- Focus lies on environmental quality & civil engineering
- Clients are among others (multinational) companies, (local, regional & national) authorities, investors, lawyers
- So what do my colleagues and I do …?

So what do my colleagues and I do …?

- Find the best & cost-effective remediation solution for each individual site

ISCO Fenton's

steam injection

excavation

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Introduction

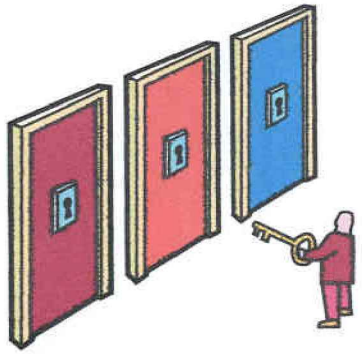
- Applied in the Netherlands (since 1999), started with Fenton's reagens currently persulphate is *hot*

- Popular
  - it is simple – inject an overdoses strong oxidant, when in contact with a reduced specie e.g. a contaminant complete degradation occurs
  - it is capable of large mass reduction
  - it is fast
  - no above ground waste treatment

Introduction

- ISCO includes applications of different oxidants, each with its own field of application, contaminant situation, and results that can be achieved

  - Fenton's reagens (classic & modified)
  - ~~ozone (C-Sparge™)~~
  - ozone/peroxide (Perozone™)
  - permanganate
  - ~~persulphate (activated & non-activated)~~
  - ~~solid peroxides (*slow oxygen release compounds*, ORC®)~~



Fenton’s reagens

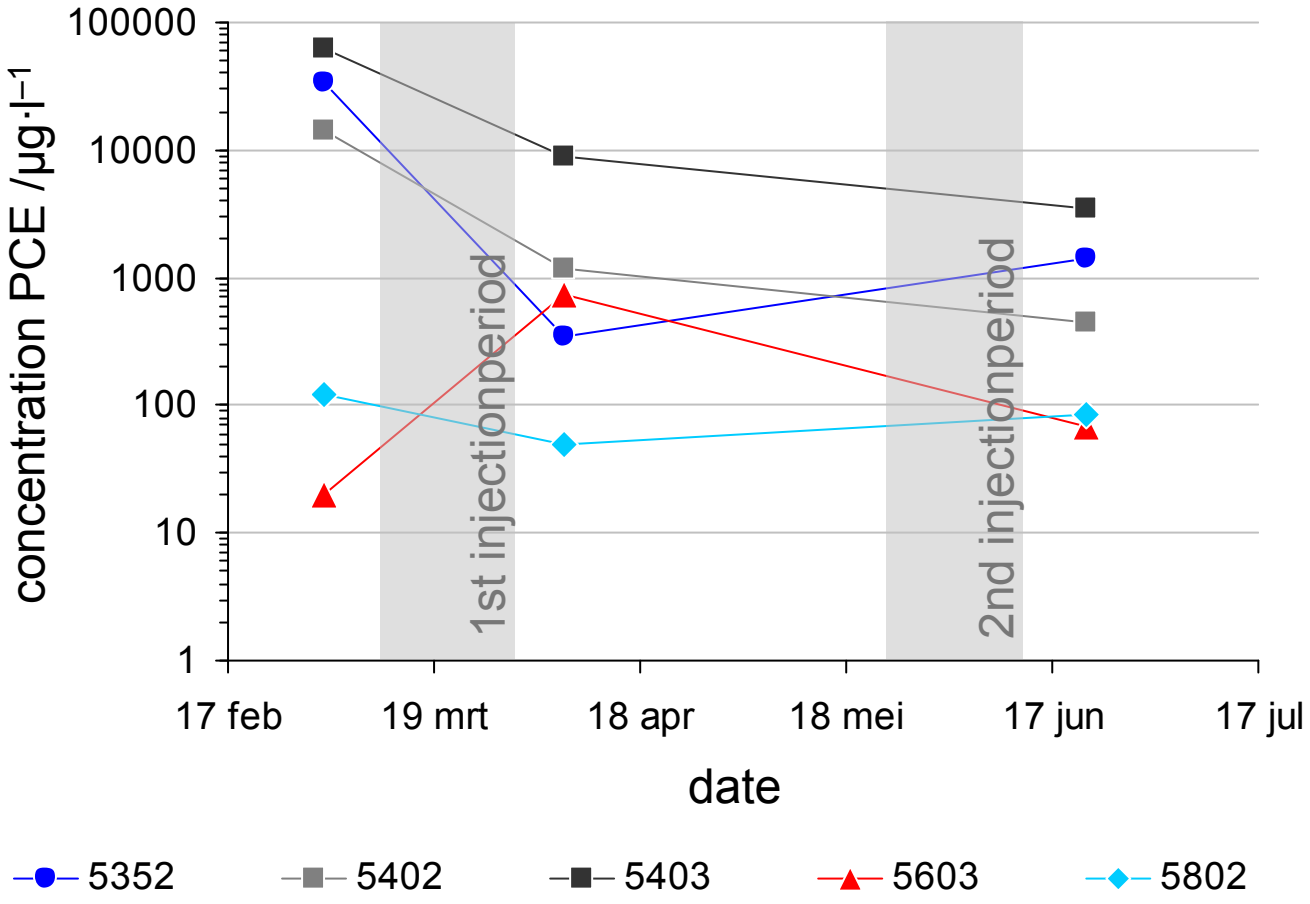
Fenton's reagens

- Fenton's reagens
  - typically used in source zones
  - short remediation time (<2 yrs)
  - typically 2 injection periods
  - high level of safety required → restricted access

- Mass removal technique
  - mass removal typically between 70 and >95%
  - target values defined on groundwater concentration e.g. for PCE 40 $\mu g \cdot L^{-1}$ are not advisable
  - high concentration in source zone remain after remediation

Fenton's reagens | example

- PCE injection wells



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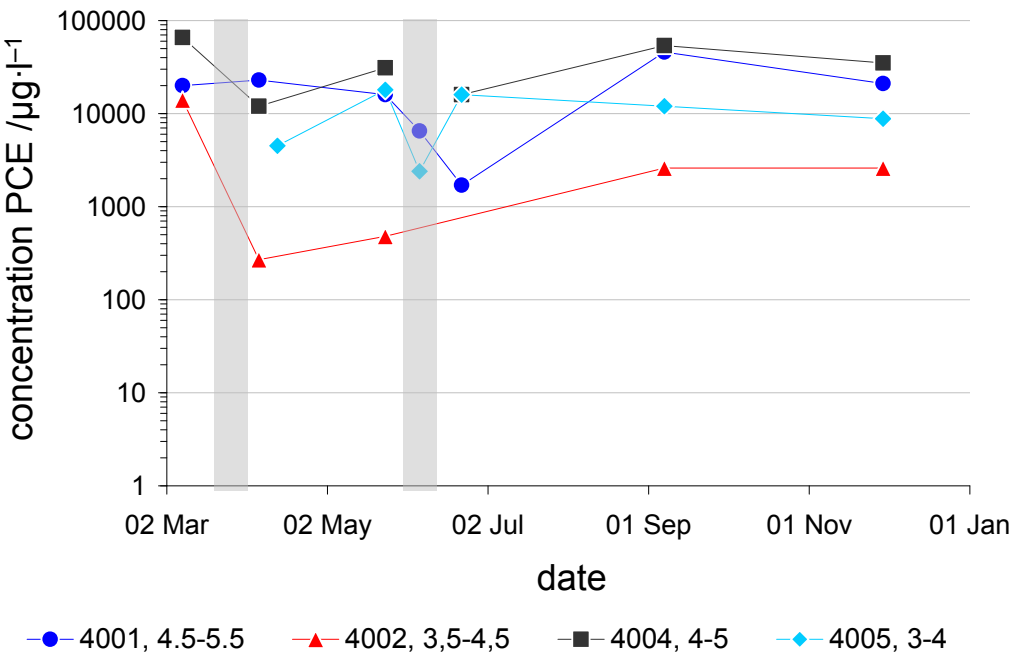
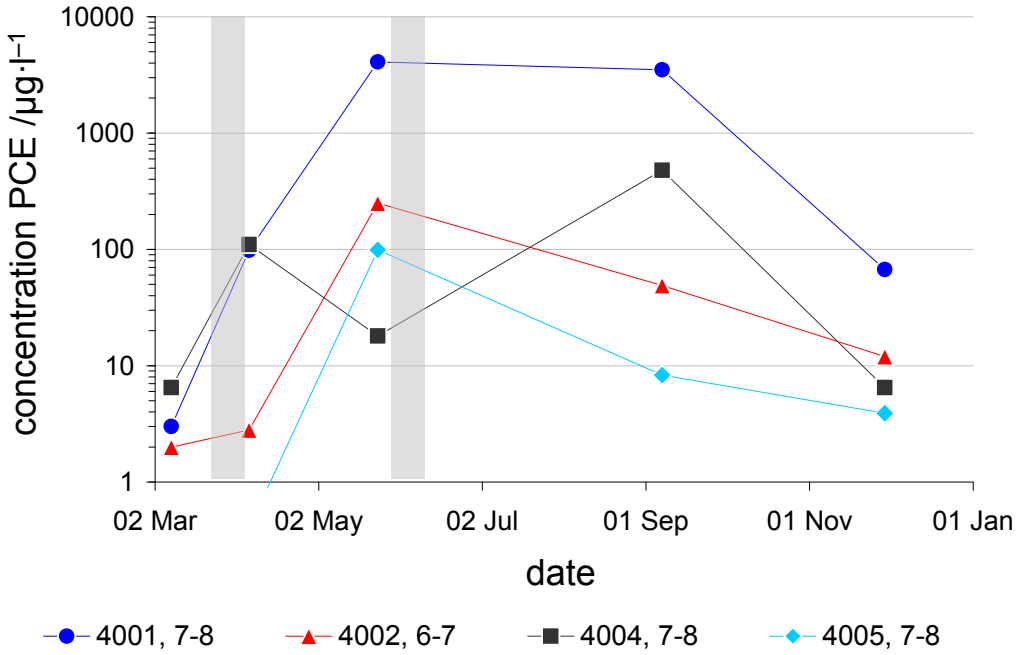
example

shallow monitoring screens



deep monitoring screens



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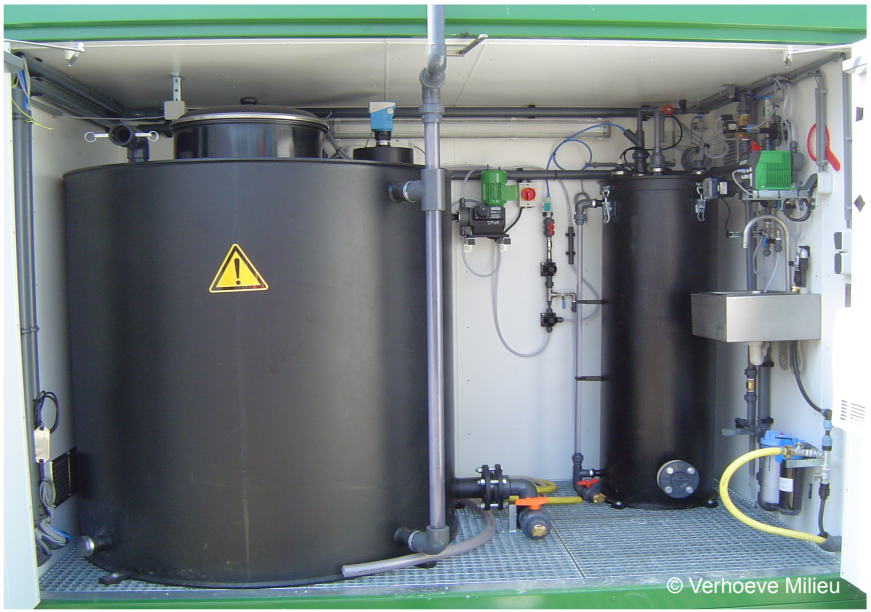
Fenton's reagens | lessons learned

- Results
  - mass reduction 55 - 99% e.g. 5403; 63,000 → 3,500 $\mu g \cdot L^{-1}$
  - results in monitoring wells not conclusive:
    favourable e.g. 4004, 4-5; 66,000 → 16,000 $\mu g \cdot L^{-1}$
    unfavourable soil sampled approx. 1 m from injector 5352 with mass reduction 96%; 34,000 → 1,400 $\mu g \cdot L^{-1}$ contained 710 $mg \cdot kg^{-1}$ PCE
  - mobilisation / displacement due to injection of large volumes
  - soil chemistry – SOD of lesser importance, buffer capacity and Fe(II) availability governing

Ozone & ozone/peroxide



Ozone | C-Sparge™

- Ozone
  - continues co-injection of O_3 in an adapted air sparging system
  - typically used in reduction of groundwater plumes
    … sometimes used in source zones **without** DNAPL
  - extended remediation time (3-5 yrs)
  - high level of safety required → O_3 production on-site

- Concentration reduction technique
  - target values defined on groundwater concentrations e.g. for PCE 40 $\mu g \cdot L^{-1}$ (or lower) are realistic

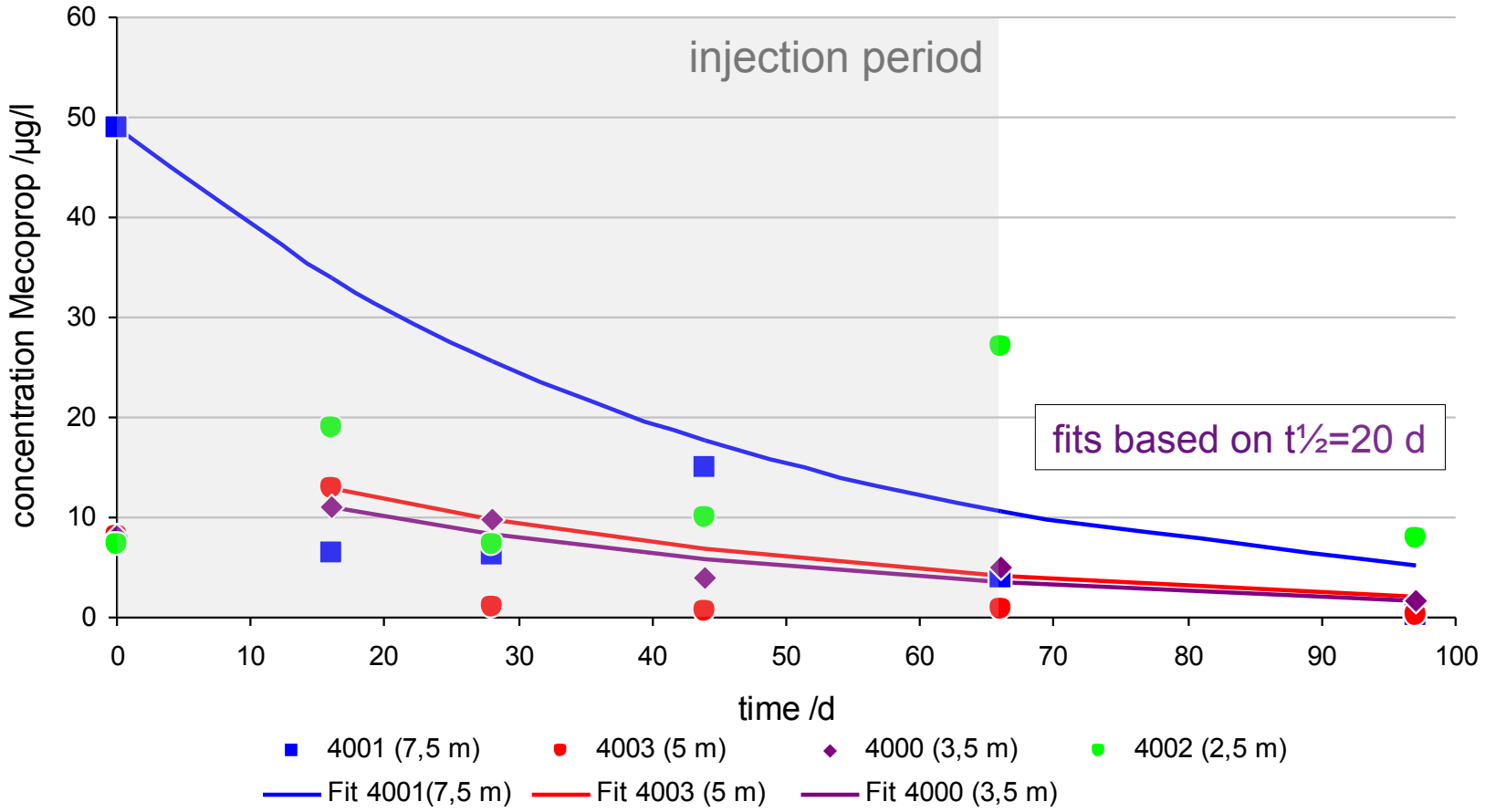
Ozone/peroxide | Perozone™

- Ozone/peroxide
  - co-injection of O_3 & hydrogen peroxide in an adapted air sparging system
  - typically used in source zones **without** DNAPL
    … also used in reduction of groundwater plumes
  - extended remediation time (3-5 yrs)
  - high level of safety required → O_3 production on-site

- Mass / concentration reduction technique
  - target values defined on groundwater concentrations e.g. for PCE 40 $\mu g \cdot L^{-1}$ (or lower) are realistic
  - mass reduction typically 70 and >99%

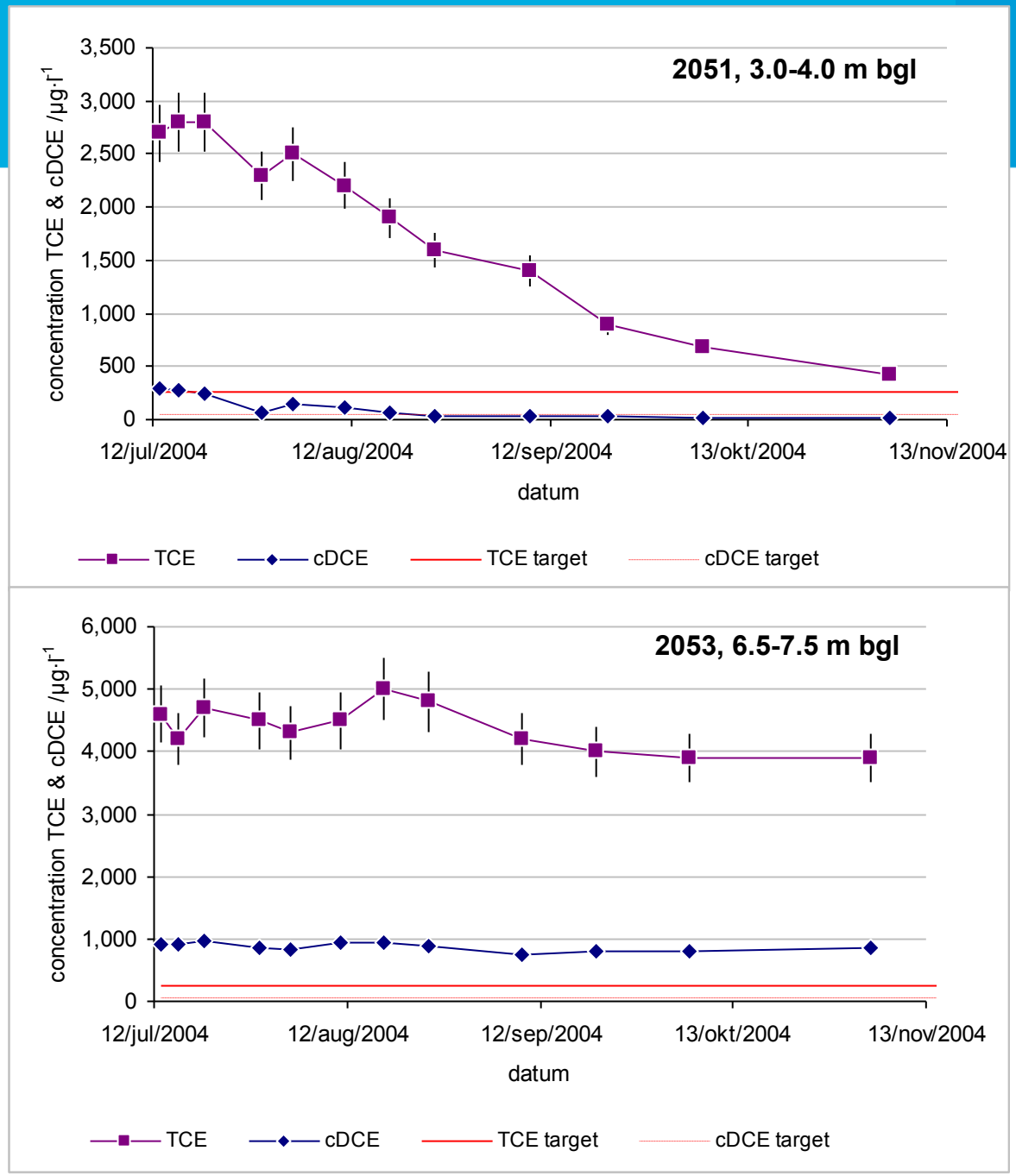
Ozone/peroxide | example 1

- Degradation of Mecoprop, source zone



example 2

- TCE & cDCE source zone (no DNAPL)



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Ozone/peroxide | lessons learned

- Results
  - mass reduction 80 - >95%
  - results in monitoring further down gradient or deeper disappointing (no effect)
  - processes known from air sparging are of importance e.g. radius of influence, convection, preferential (air) flow paths, soil heterogeneity
  - soil chemistry – SOD of lesser importance rule of thumb approx. 15 g O_3 needed per m^3 soil

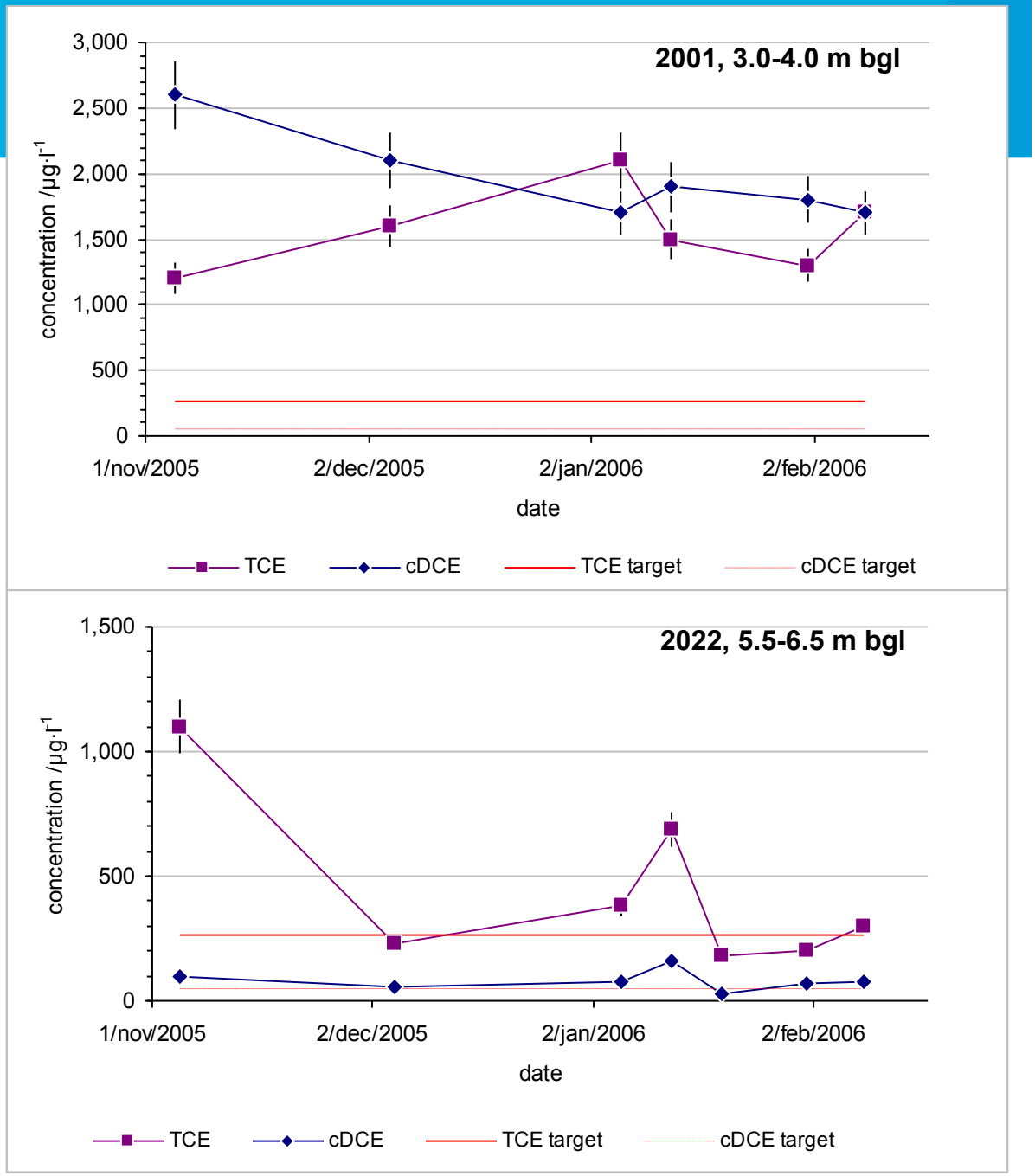
Permanganate

Permanganate

- Permanganate
  - typically used in source zones
    … not cost-effective in plume areas
  - used in low (2-4%) solutions
  - short remediation time (<2 yrs)
  - stable (mild) oxidant → less rebound
  -
- Mass / concentration reduction technique
  - mass removal typically between 70 and >95%
  - target values defined on groundwater concentration
  - can be used as polishing step after e.g. Fenton's

example

- TCE & cDCE reduction in source zone (no DNAPL)



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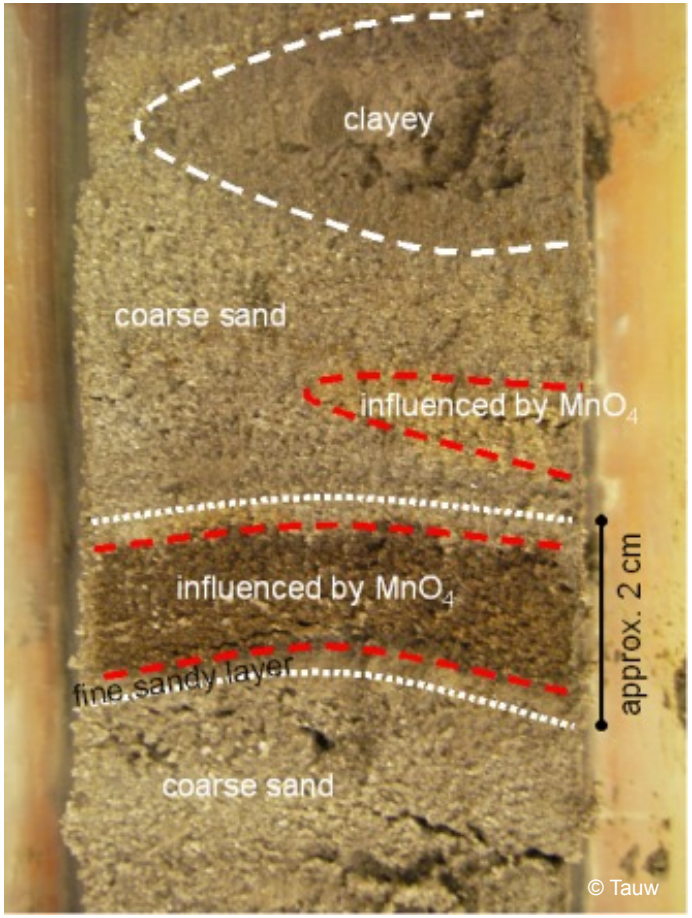
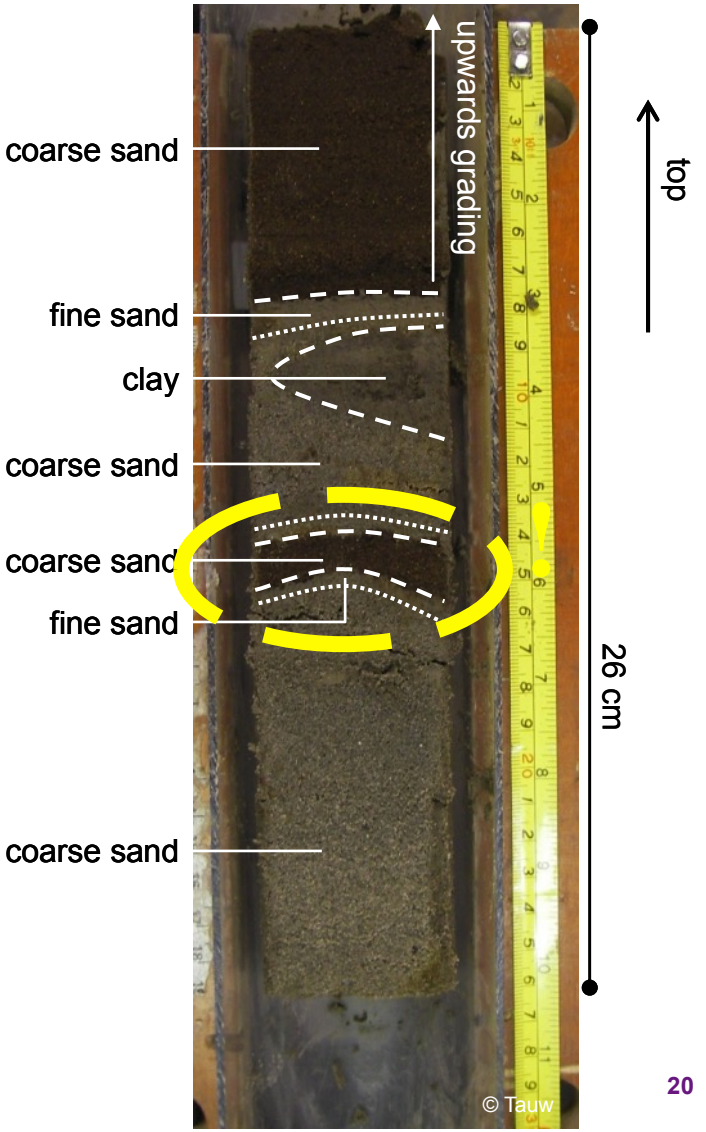
Permanganate | example

- Soil heterogeneity





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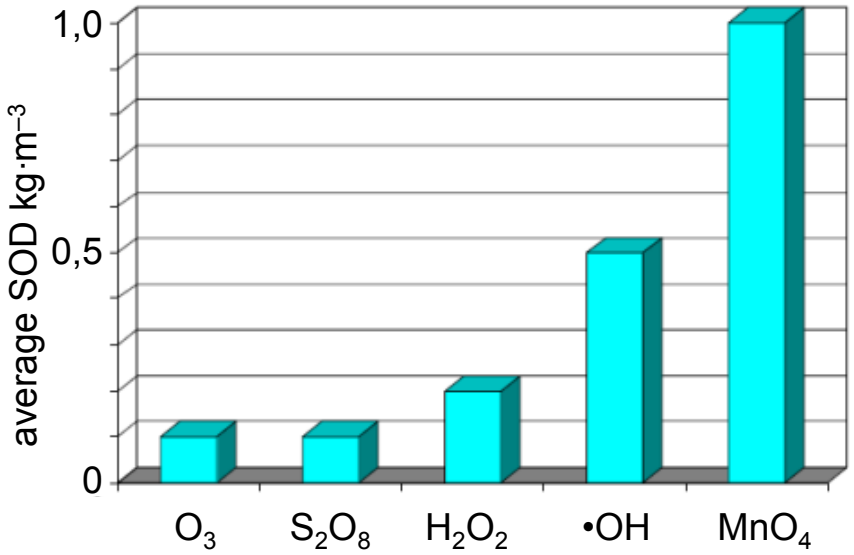
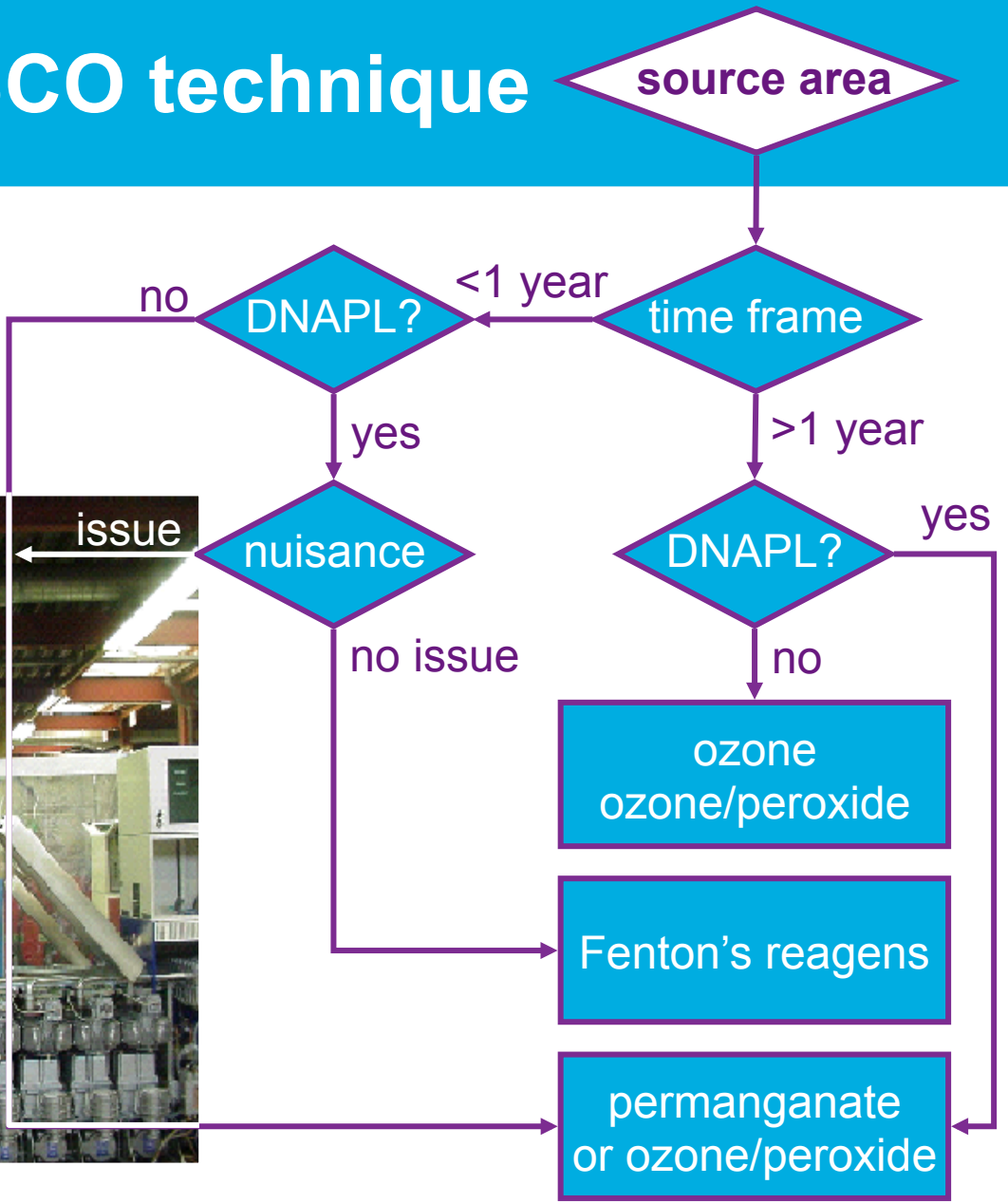
Permanganate | lessons learned

- Results
  - reduction groundwater concentrations sufficient, over-all results disappointing often 2 injection periods necessary
  - soil heterogeneity important parameter
  - soil chemistry – SOD crucial rule of thumb inject excess MnO_4 to overcome all SOD
  - soil reactivity high compared to US references



(Brown, 2003)

Selection ISCO technique



Summarising

- ISCO is **not** a silver bullet solution
  → ISCO part of a complete remediation strategy

- Limiting factors
  - remediation target values
    → technique and site specific
  - soil heterogeneity
    → where is the contaminant going? oxidant?
    → specific soil survey & optimal selection of injection system
  - soil chemistry
    → do laboratory test on site samples
    → pilot remediation

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Fenton's reagens | contaminants

group	specific contaminants
TPH	light TPH-fraction, alkenes **heavy TPH-fraction, alkanes**
CHC	PCE, TCE, DCE & VC, chlorobenzenes, chlorophenols **Tetra, Chloroform, 111TCA & 112TCA, PCB's,**
aromatic compounds	BTEX, naphthalene, phenols, light PAH's (2 / 3-ring) **heavy PAH's (>4-ring)**
other	MTBE

Ozone & ozone/peroxide | contaminants

group	specific contaminants
TPH	light TPH-fraction, alkenes **heavy TPH-fraction, alkanes**
CHC	PCE, TCE, DCE & VC, chlorobenzenes, chlorophenols **Tetra, Chloroform, 111TCA & 112TCA, PCB's, pesticides (POP's)**
aromatic compounds	BTEX, naphthalene, phenols, light PAH's (2 / 3-ring) **heavy PAH's (>4-ring)**
other	MTBE

Permanganate | contaminants

group	specific contaminants
TPH	alkenes **TPH, alkanes**
CHC	PCE, TCE, DCE & VC, chlorobenzenes, chlorophenols **Tetra, Chloroform, 111TCA & 112TCA, PCB's**
aromatic compounds	toluene, xylenes, phenols **benzene** ! **PAH's**
other	**cyanides**