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ISCO under Danish conditions – an overview

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Foto: Vesterbro, 2002,
COWI-Fyns County

My background (Consulting - Rambøll/COWI)

I have Performed several project with ISCO in Denmark (labtest, pilot test, full scale) during the last 8 years (mosty permangananate) – se examples:

Project	Contaminants		Scale	Client
2 Technology Temonstrations Project	PCE	Permanganate	Labtest, full scale	Danish EPA, Fyns County
Cheminova – Høfde 42	Mixed - pesticides	Permanganate, modified Fentons, Ozone/H_2O_2	Labtest, feasability studies	Danish EPA, Ringkøbing County
Kærgård site	Mixed – pharmaceutical waste, DNAPL, BTEX etc	Permanganate, Modified Fentons, Activated Persulfate Ozone/H_2O_2	Labtest, pilottest in 2010	Danish EPA, Region-Southern Denmark, Ringkøbing County

Outline

1. What is special for Denmark?
2. Experiences in Denmark
3. Barriers using ISCO
4. Perspective – Potentials for ISCO in Denmark
5. Need for Technology deveplopment

What is special for Denmark?

- Geology – many clay sites with low permeability
- Well buffered aquifers in central and eastern Denmark
- Contaminants – mostly chlorinated ethenes and oil/gasoline
- Remediation ”driver”:

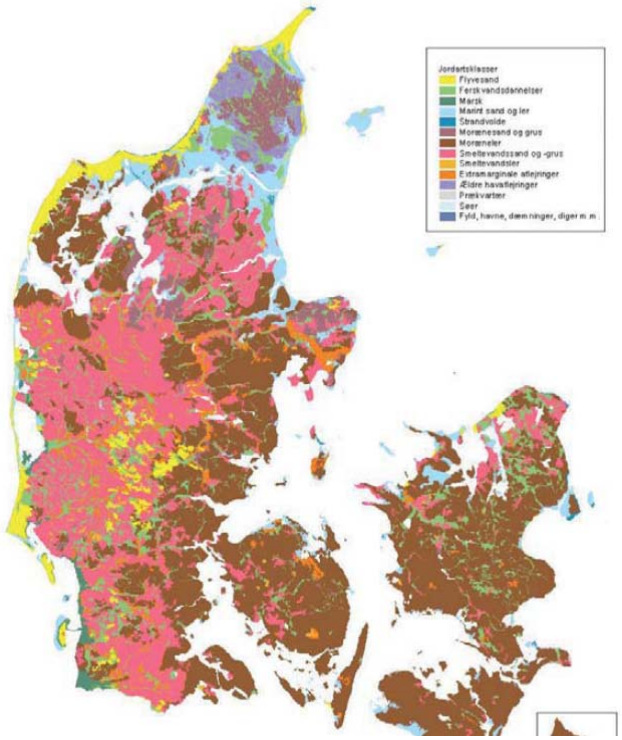
  - typically to protect drinking water aquifers
  - typically high demands for cleaning up levels

- Typical smaller sites

Danish geological conditions

Western Denmark:

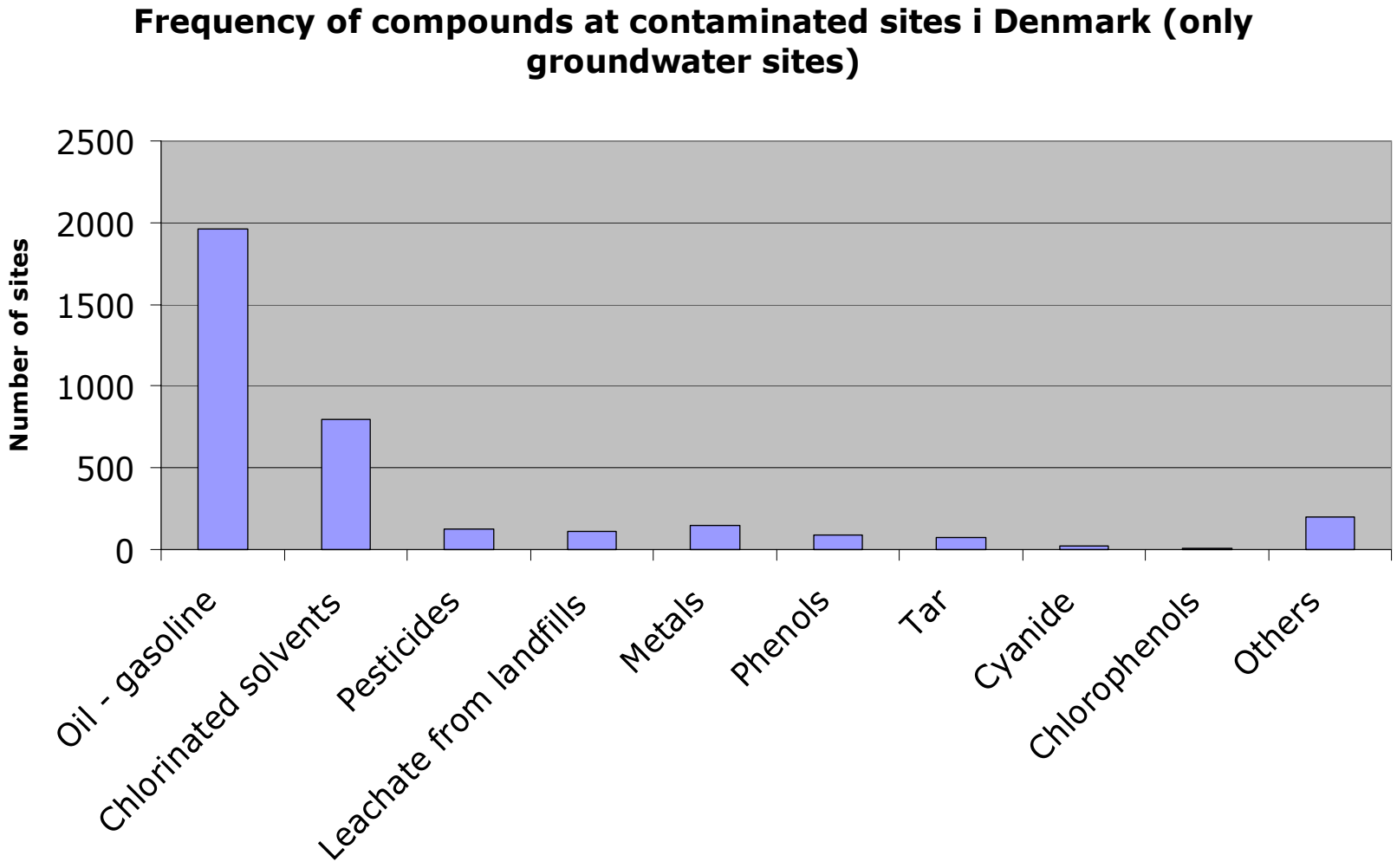
- Mostly sandy soil
- Low buffered aquifers
- Low content of lime
- Less populated
- Fewer contaminated sites to be remediated



Eastern Denmark

- Mostly clay soil
- Well buffered aquifers
- High content of lime
- Higly populated
- Many contaminated sites to be remediated

Contaminants



Kilde: Redegørelse fra Miljøstyrelsen, 1, 2009
Redegørelse om jordforurening 2007,
Depotrådet

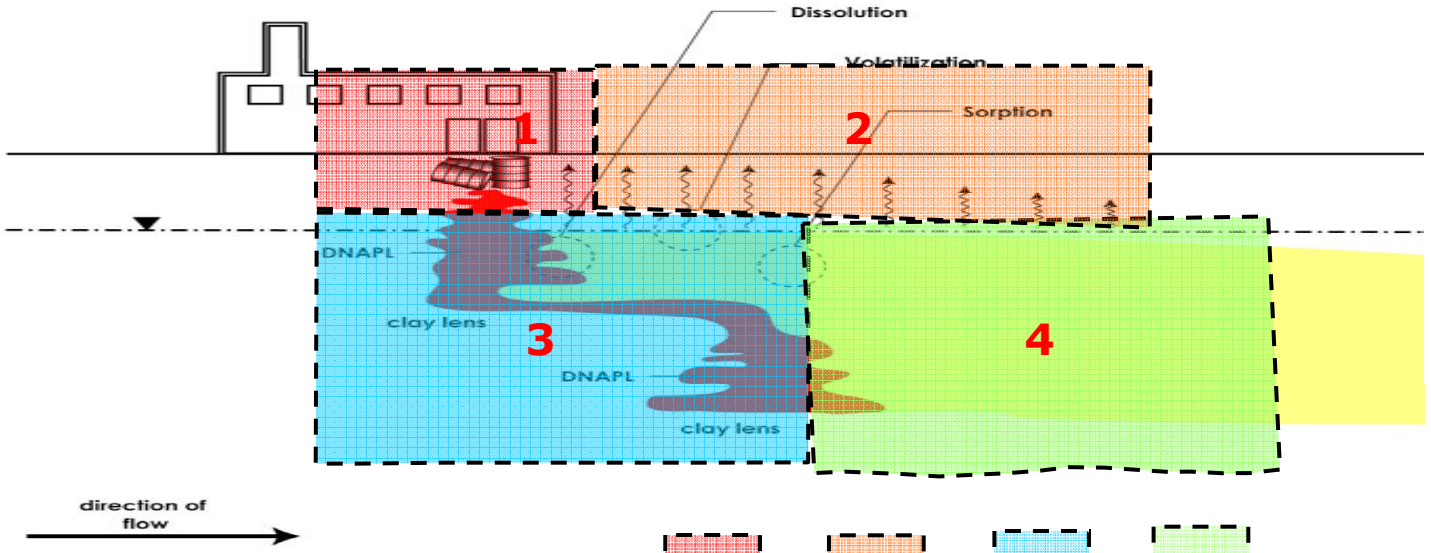
Typical inorganic groundwater chemistry

Parameter	Eastern Denmark	Western Denmark
pH	7-8	3-7
HCO3	> 300 mg/l	50 – 150 mg/l
Calcium	> 50 mg/l	< 50 mg/l
TOC (NVOC)	< 10 mg/l	< 10 mg/l
Redox	Typically anaerobic	Typically aerobic

Experiences with ISCO in Denmark

Oxidant	Experience in Denmark	
	Laboraty test	Field experience
Permanganate	Many	Many >20 sites (pilot and full scale projects) Most successfull in sand aquifers but also some succes as a polishing methods in clay
Fentons	Some (eg Kærgård Site, Cheminova Site – by ISOTEC)	Only traditionel Fentons Some (< 5-10 sites) – most at oil/gasoline sites Variable success
Ozone	Few (eg Kærgård and Cheminova site – by ISOTEC) – good results	Few (not so successfull)
Peroxone (Ozone/ H_2O_2)	(eg Kærgård and Cheminova site - ISOTEC)- good results	Few (1-2) – not so successfull
Persulfate	Few	Few (~3-4 pilottest/polishing) – including 1 S-ISCO)

Target areas – where have we used ISCO



Oxidant	1	2	3	4
Permanganate	÷	÷	+	(÷/+)
Fentons	(÷)	÷	+	÷
Ozone	+	÷	+	÷
Persulfate	÷	÷	+	÷

Degradation effect – Danish experiences

Compound	Permanga-nate	Fentons (modified)	Persulfate (MFR)	Ozon/H2O2
CAH				
PCE	XXX	XXX	XXX	XXX
TCE	XXX	XXX	XXX	XXX
DCE	XXX	XXX	XXX	XXX
VC	XXX	XXX	XXX	XXX
Phenols	XX-XXX	XXX	-	XXX
BTEX's				
Benzene	X	XXX	XXX	XX
Toluen	XX	XXX	XXX	XX
Pesticides				
Parathion	XXX	XXX	-	XXX
Malathion	XXX	XXX	-	XXX
MCPA	XXX	XXX	-	XXX
N-organic compounds				
Aniline	XXX	XXX	XXX	XXX
Pharma Products				
Sulfonoamides	XX-XXX	XXX	XXX	XXX
Barbiturates	X - XX	XXX	XXX	XXX

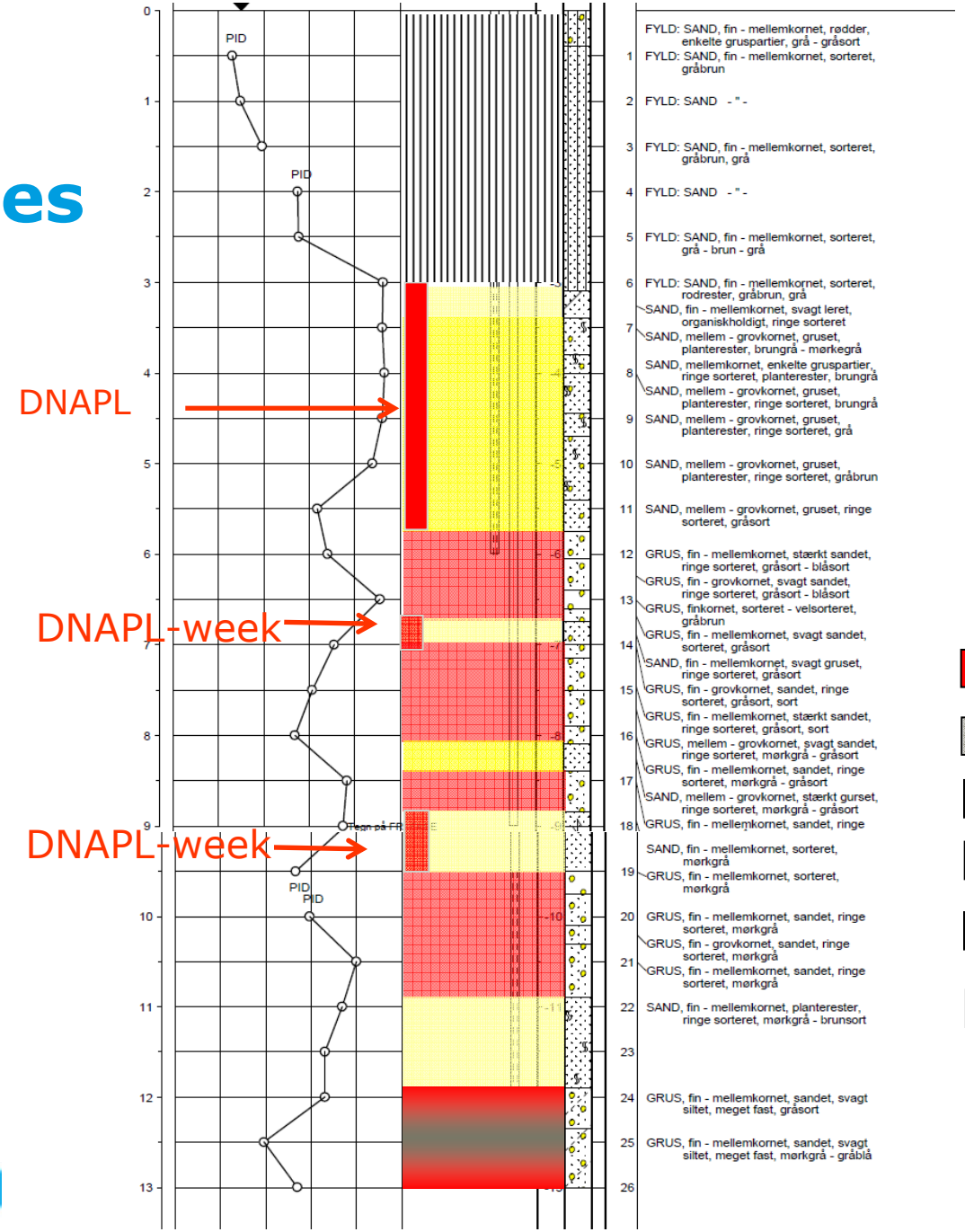
Efficiency

High

Medium

Low

Major challenges



DNAPL

Fyld: sand

Sand: fin/melllem

Sand: mellem/grov

Sand: grov

Grus

Grus: siltet -fast

RAMBØLL

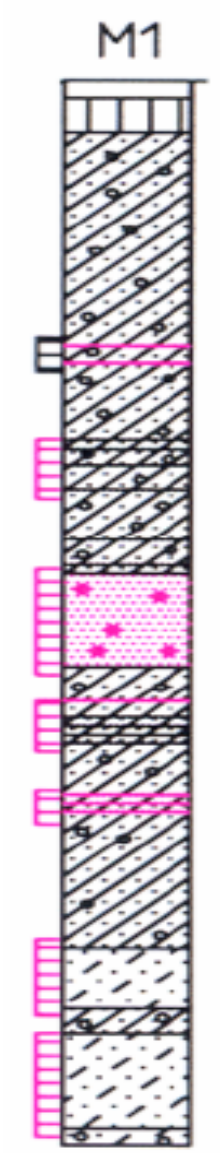
Remediation in clay soils (permanganate)

- Typically used in combination with source removal (escavation)
- There is some effect – but documentation has normally not been so good

Remediation in clay soils with permanganate

(Experience from Miljøprojekt 1066)

- Time consuming (many years before complete remediation)
- High consumption of permanganate
- Partial remediation of the matrix could result in reduction of the flux of PCE to the sand lenses
- Transport of permanganate into the clay matrix via diffusion was app. 15 cm in oxidised and 2-3 cm in reduced zone (in one year)



Barriers for ISCO in Denmark – some common concerns/myths?

- It does not work in low permeable soil
- Impact on groundwater chemistry (eg mobilization of metals)
- It's not effective against DNAPL/NAPL
- You can't reach groundwater clean up criteria
- It's too expensive
- Lack of success stories

Barriers for ISCO in Denmark

Oxidant	Potential barriers
Permanganate	•Spreading af permanganate to waterbodies •DNAPL remediation??
Fentons	•High buffercapacity at many sites •Difficult to control in the field
Ozone	•Uncontrolled spreading of ozone
Ozon/H202	•Only few relevant sites eg Kærgård (on site treatment not in-situ)
Persulfate	•Can lower pH •Expensive

Potential use of ISCO in DK

Oxidant	Potential use in DK	Contaminants	Comments
Permanga-nate	Medium - High	PCE, TCE, DCE, VC	•Sandy aquifers •Source and plume
Fentons	Medium	Mixed and special contaminants, oil/gasoline, pesticides	•DNAPL sites
Ozone	Low	PCE, TCE, oil/gasoline other?	•Unsaturated zone
Ozon/H202	Low	complex groundwater contamination, landfill leachate	•On – site treatment
Persulfate	?	Mixed and special contaminations, oil/gasoline	•Low permeablity •Combine with thermal methods •DNAPL??

Cost (permanganate) – according to Miljøprojekt Nr. 1241

- Not any systematic cost evaluation of Danish projects
- ISCO is considered as cost effective compared to other in-situ methods
- On the basis of the experience from "Miljøprojekt 1241", it was assessed that the saturated zone could have been cleaned up more effectively and cheaply using only chemical oxidation (without air sparging)

Need for further knowledge in Denmark

1. Injection methods/strategy (eg direct push techniques, traditionel screened wells, recirculation, mixing of chemicals eg)
2. Remediation in low permeable soil
3. DNAPL/NAPL remediation
4. Remediation of oil/gasoline
5. Combination of ISCO with other methods eg:
   – treatment trains eg Fentons and biological methods
   - thermal and Persulfate
6. General ”State of the art” -
7. Comparison of methods eg:
   - cost
   - contaminants
   - DNAPL
   - side effect like mobilisation of metals

THANK YOU

Potential and perspective for ISCO - according to a status report from the Danish EPA - 2009

Summary:

"**ISCO is assested to have a big potential** to remediate chlorinated solvents, but also other contaminants like oil and gasoline, tar compounds and pesticides"

The application of the method is in growth, but there is a need for further **testing and documentation**. Furthermore, there is a need for assessment of **different means of oxidation**, and a deeper understanding of related **geochemical effects** as well as better methods for optimal management of the **injection** of chemicals

Permissions

- Adding chemicals to the subsurface require a permission from the local government (Miljøbeskyttelseslovens § 19 stk 1)
- Project performed by the Regions: ("offentlige undersøgelses- og afværgeindsats (inkl. Værditabsordningen) kan jf. §**63 i Bekendtgørelse af lov om forurenet jord** fritages for godkendelse efter Miljøbeskyttelsesloven - dog gælder forskellige undtagelser herfor bl.a. konflikter med EU lovgivning

A permission will normally require:

1. Project description
2. A risc assessment (eg metal mobilisation, spreading to nearby waterbodies etc.)
3. An "Emergency plan" – if something goes wrong