

Innovative ZVI application for sustainable remediation of chlorinated solvent plumes

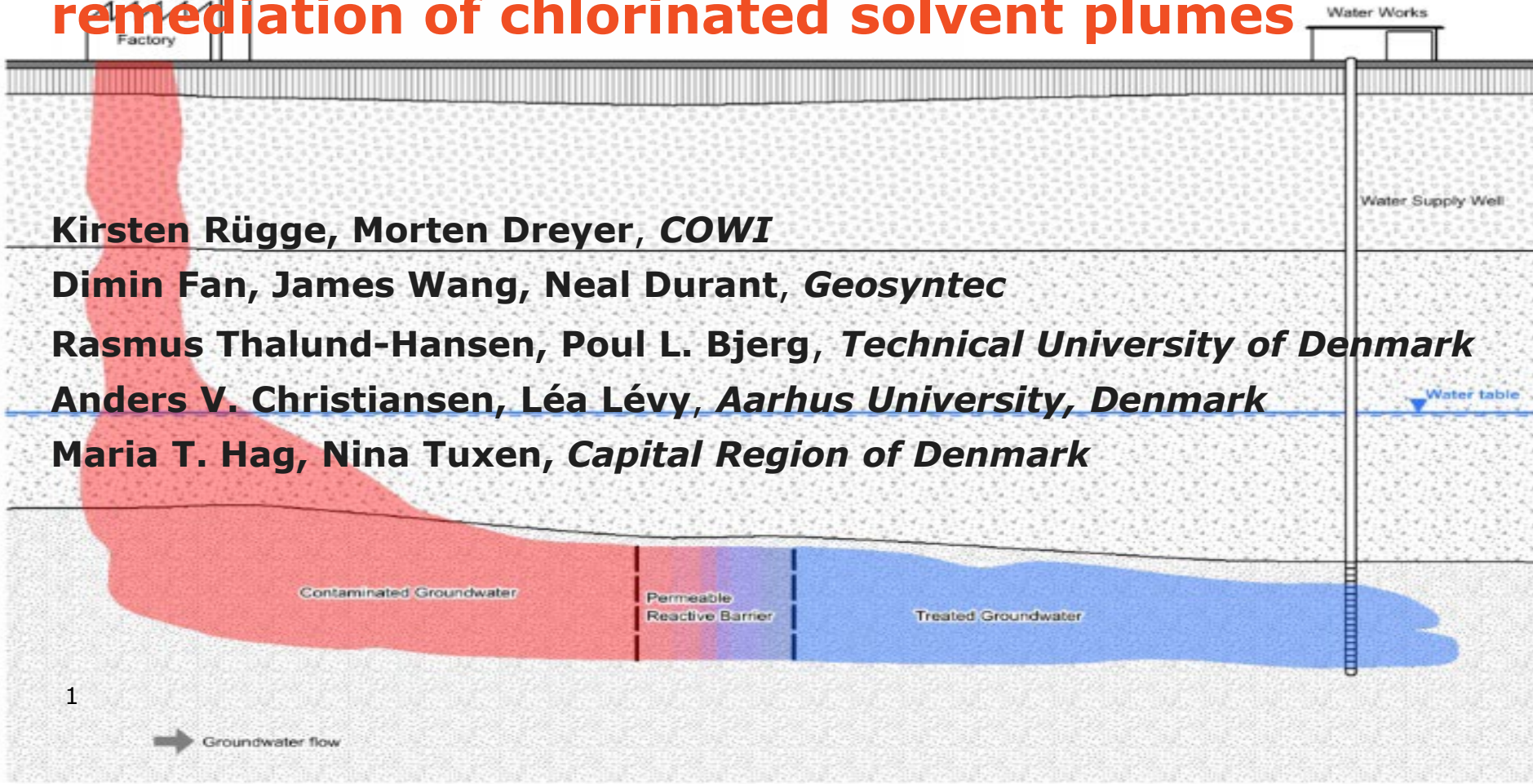
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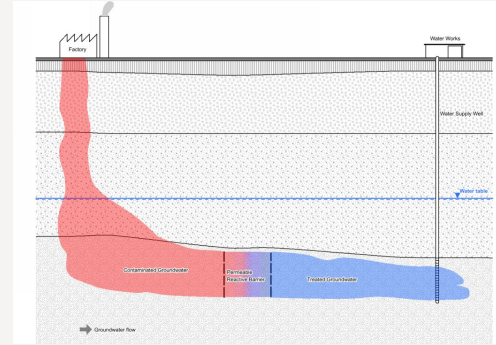
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Scope of Study



To develop a sustainable method for remediation of chlorinated solvent plumes

- > Inject ZVI in combination with organic substrates and bacterial culture into the groundwater to create a PRB with combined abiotic and biotic degradation
- > Monitor effectivity and longevity
- > To develop a geophysical method for documentation of injection, DCIP
- > Use multiple lines of evidence to do document distribution and degradation
- > Monitor production of methane and vinyl chloride in groundwater and distribution to soil vapor

Phase 1, laboratory

- > Microcosm: five ZVI products (two ZVI-OCs, three S-ZVI products), KB-1[®] culture
- > Column: two ZVI products (one ZVI-OC and one S-ZVI) to evaluate treatment longevity and reaction kinetics for design of PRB

Conclusions

- > ZVI-OC: Complete degradation of TCE and cDCE after bioaugmentation with KB-1[®] culture
- > Design parameters for the PRB obtained

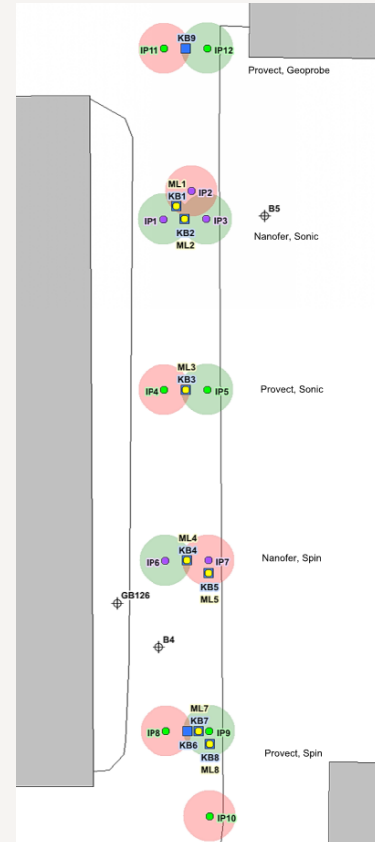


Phase 2, injection test

- > Three different injection methods:
Sonic, Spin[®] injection, Geoprobe DPT
- > Two different products

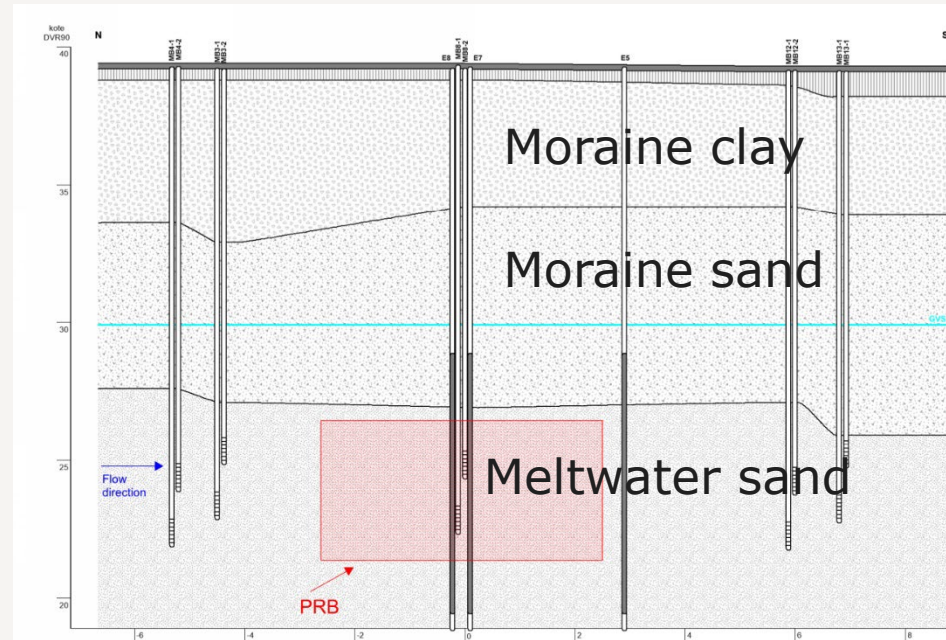
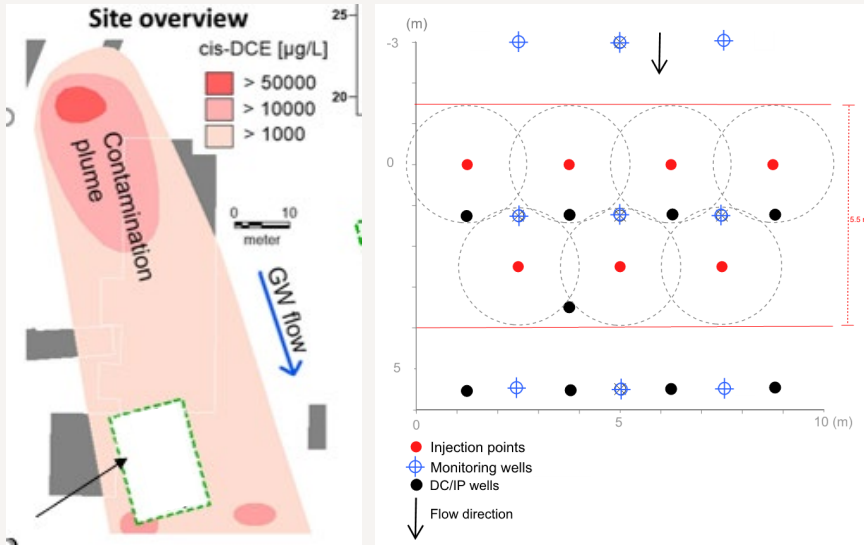
Conclusions

- > ROI 0,75 - >1,75 m
- > Geoprobe is recommended, top-down
- > ZVI-OC is recommended for the PRB



Phase 3, PRB

- Creating PRB with ZVI-OC and KB-1[®] culture
- Monitoring



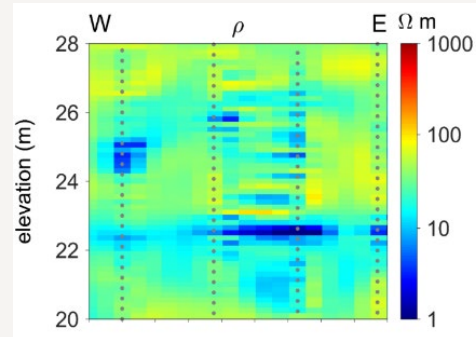
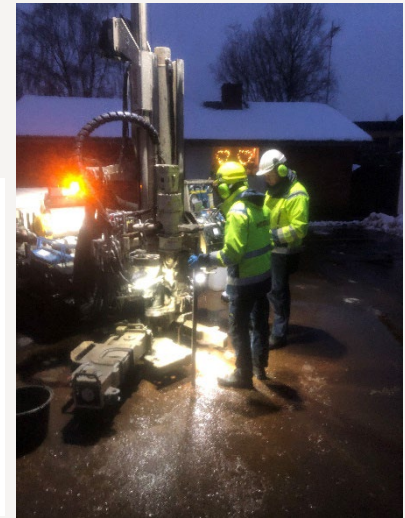
Documentation/monitoring

> Field measurements

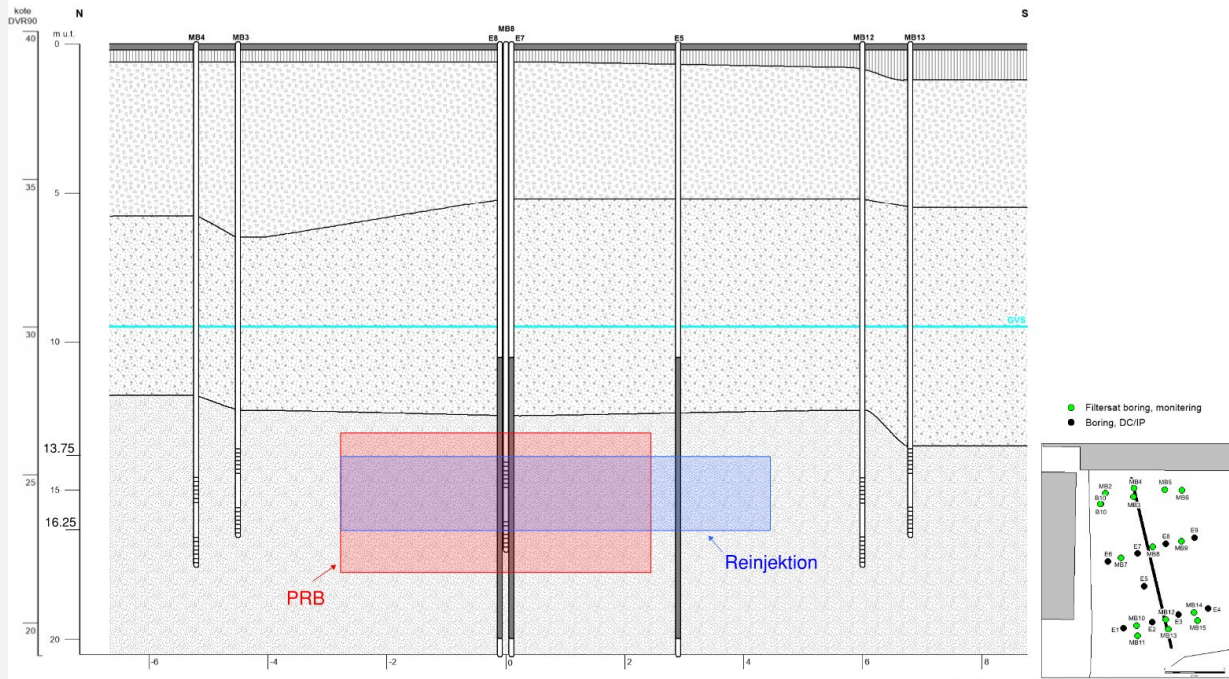
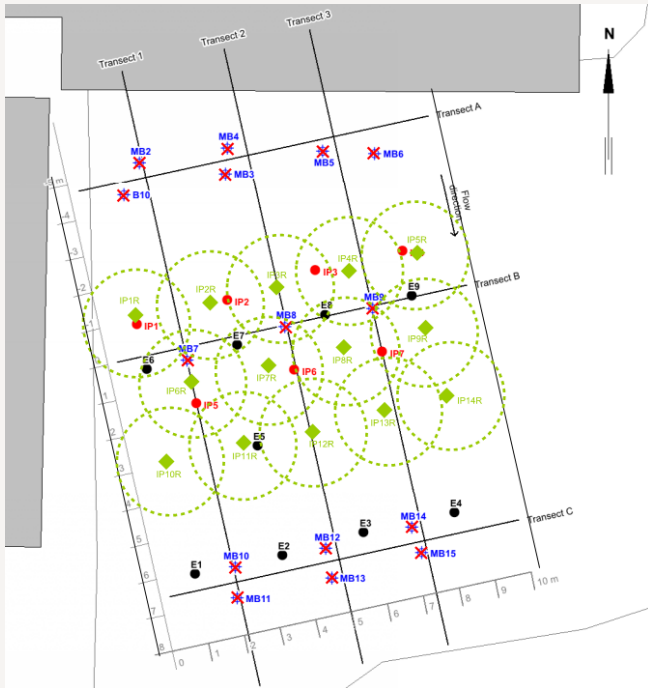
- > Intact soil cores: visual inspection, magnetic susceptibility
- > MIP/EC, DCIP
- > Groundwater level elevation, pH, oxidation-reduction potential (ORP), electrical conductivity, dissolved oxygen, and temperature

> Laboratory analyses



- > cVOC concentrations
- > Dissolved hydrocarbon gases (ethene, ethane, methane), acetylene
- > Metals (including iron, calcium, magnesium, and manganese)
- > Anions (including chloride, sulfate, and nitrate)
- > Total organic carbon (TOC) and carbonate alkalinity
- > CSIA
- > Bacterial analysis, vcrA etc.
- > Fatty acids
- > Soil gas analysis (methane, VC)

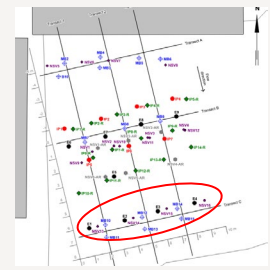
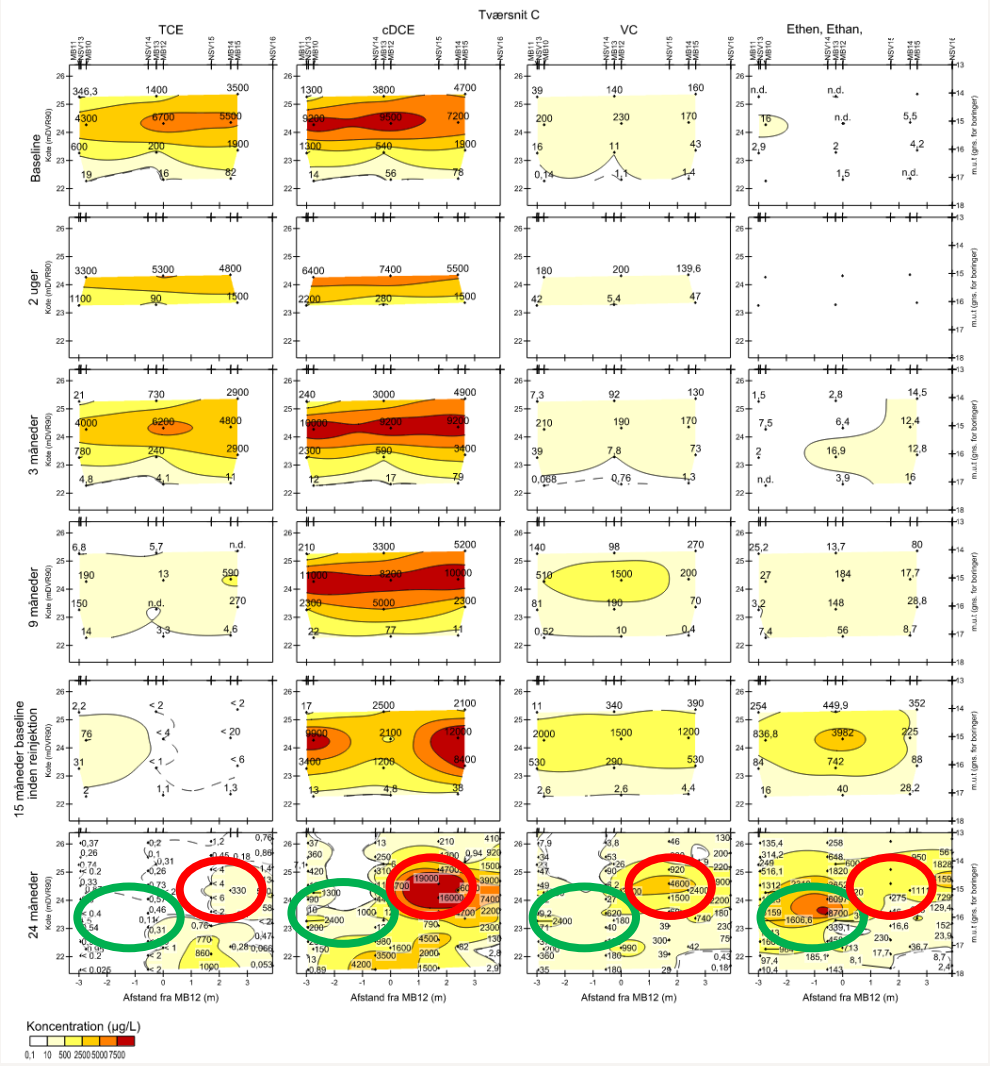


Phase 4, Reinjection and monitoring

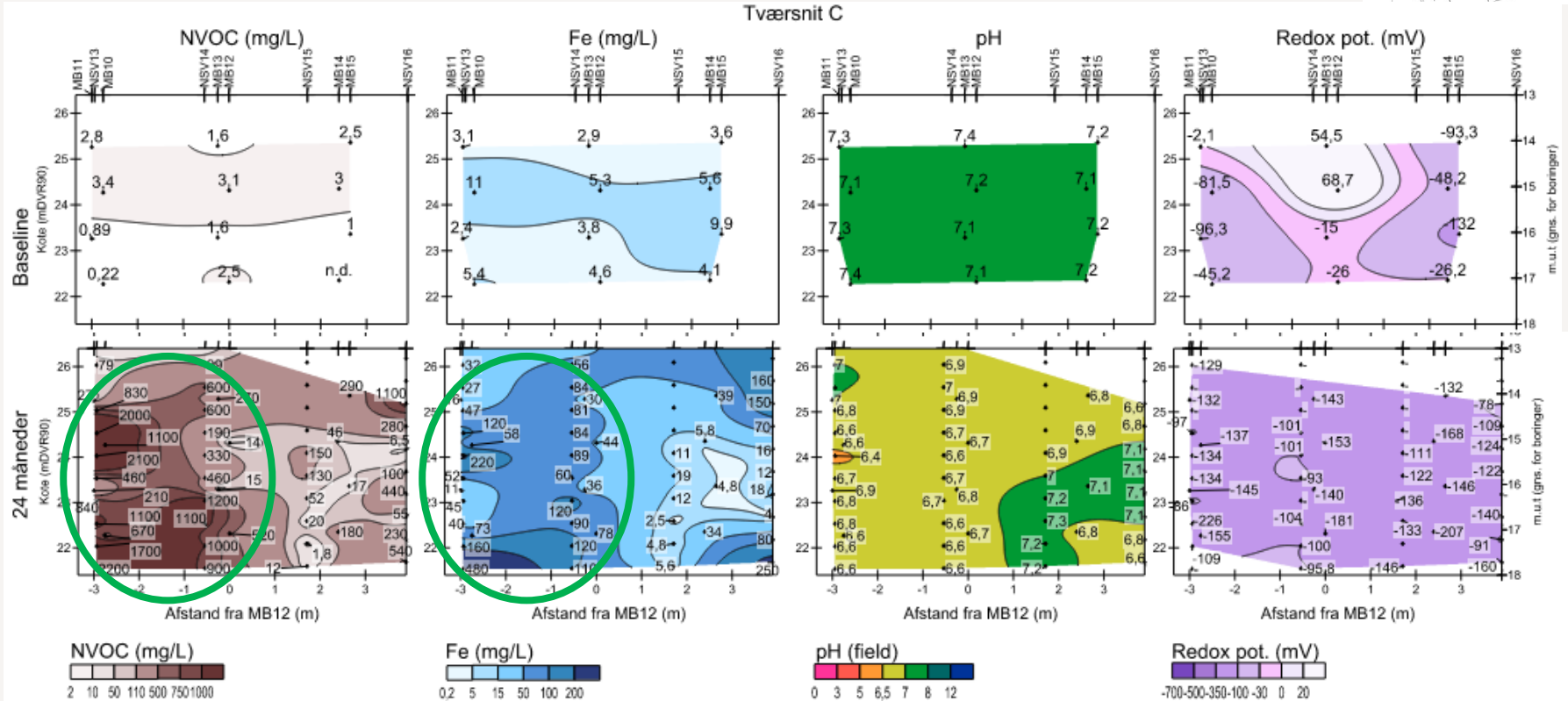
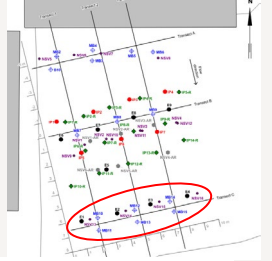


Transect C

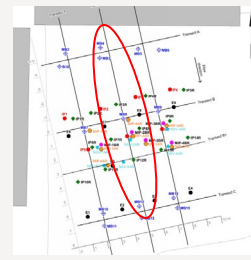
-  Active area
-  Control/ Less active area



Transect C

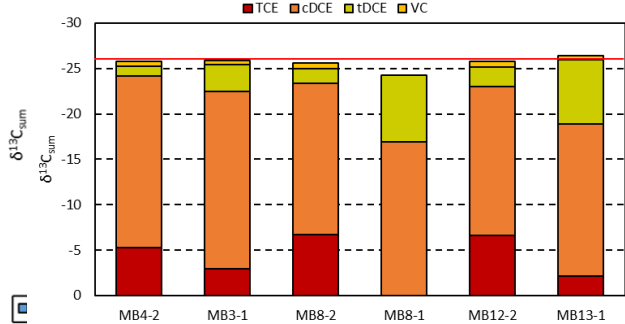


CSIA

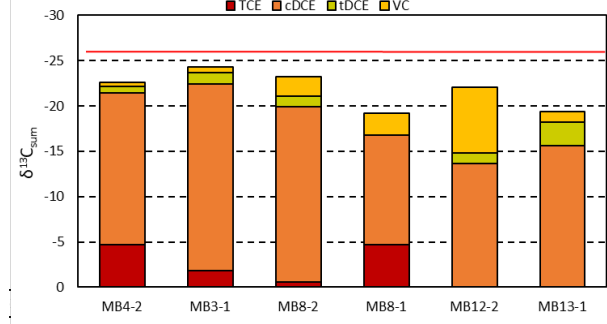


$$\delta^{13}C_{sum} = \frac{[TCE] \cdot \delta^{13}C_{TCE} + [cDCE] \cdot \delta^{13}C_{cDCE} + [tDCE] \cdot \delta^{13}C_{tDCE} + [VC] \cdot \delta^{13}C_{VC}}{[TCE] + [cDCE] + [tDCE] + [VC]}$$

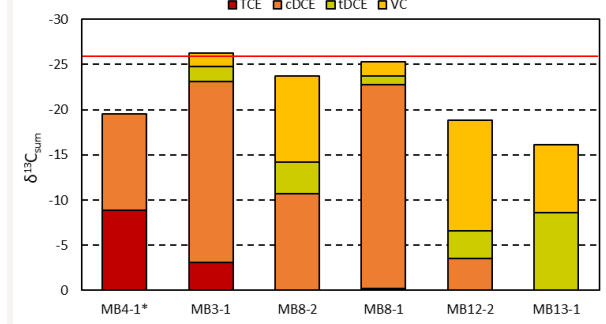
$\delta^{13}C_{sum}$ - Baseline/2 uger



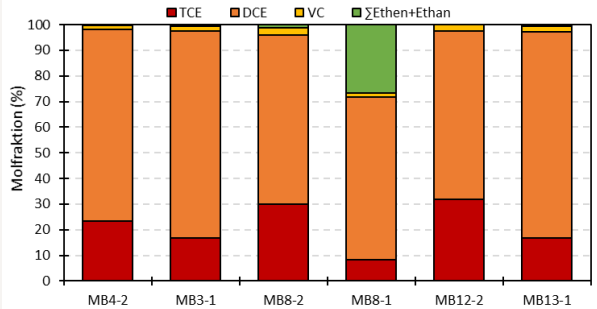
$\delta^{13}C_{sum}$ - 9 mdr.



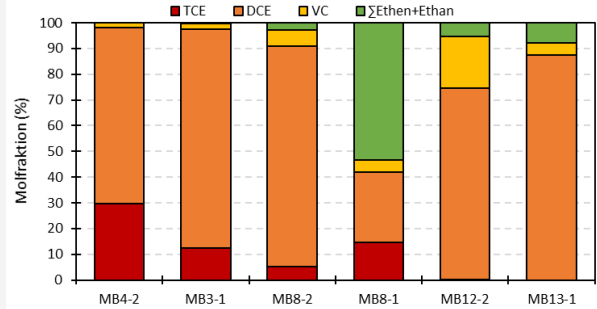
$\delta^{13}C_{sum}$ - 24 mdr.



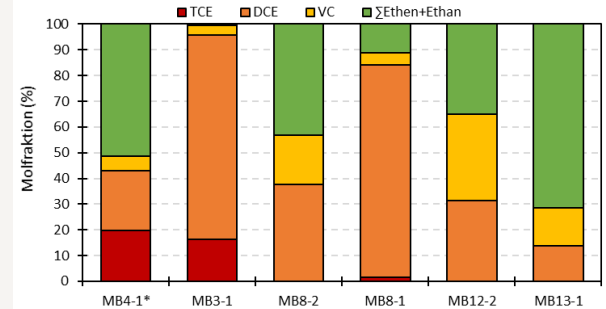
Baseline/2 uger efter



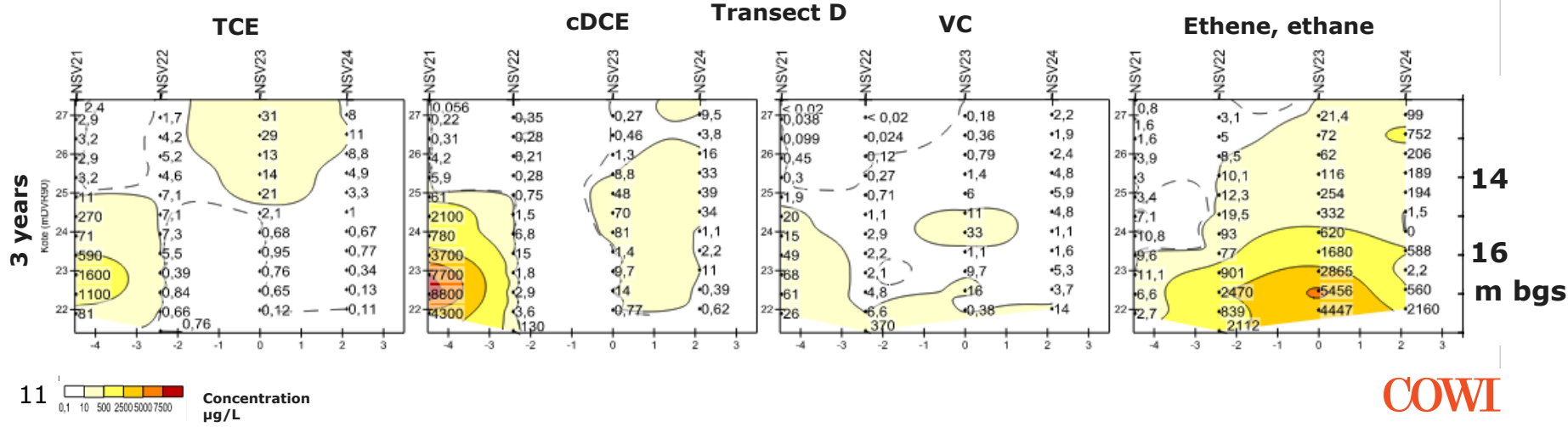
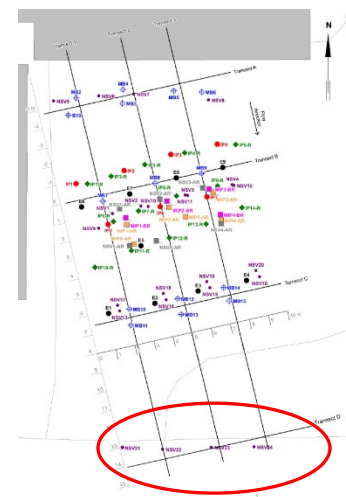
9 mdr.



24 mdr.

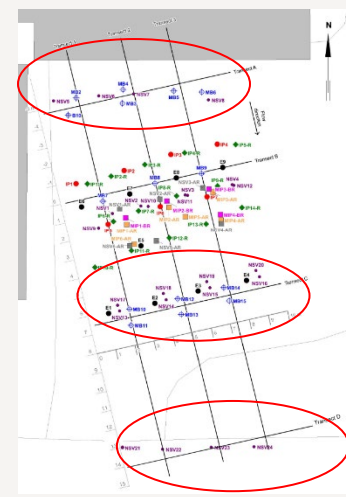


GW monitoring, Transect D



Contaminant mass discharge

sum, cVOC	Transect A (mol/year)	Transect C (mol/year)	Difference (A-C) (%)	Transect D (mol/year)	Difference (A-D) (%)
Baseline	4,3	4,5	5	-	-
3 months after	4,2	4,6	8	-	-
9 months after	5,9	3,8	-35	-	-
15 months after (baseline before reinjection)	6,0	3,9	-34	-	-
24 months after	5,0	3,1	-38	-	-
36 months after	7,0	3,4	-51	0,5	-93



Conclusions

- › Production of cDCE and VC indicates a large degree of biotic degradation
- › In the active zone, almost complete degradation is observed
- › The use of CSIA, has given a second line of evidence with respect to both production and degradation of the cVOCs
- › Dual isotopic plots over time indicate a change from solely biotic degradation to now a combined biotic and abiotic degradation
- › Production of methane is decreased compared to other projects
- › Production of methane and vinyl chloride is not a problem in soil gas
- › DCIP is a good method for documentation



Take Home Messages

- > ZVI-OC in combination with KB-1[®] culture is a promising method for remediation of chlorinated solvent plumes
- > Adding a methane inhibitor is a good idea in urban areas
- > Future focus should address efficient injection methods and distribution of amendments
- > Use of multiple lines of evidence gives a much better understanding of the processes

