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Optimising Chances

Intersol 2016 - Lille, France

Flow Pathway Networks for improved in situ Remediation using the „i-SAV©“ Process

Gordon H. Bures, M.Eng.

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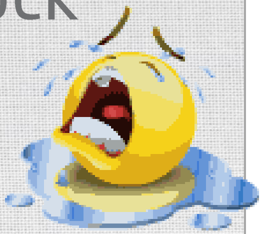
Limitations to in situ Remediation

In situ remediation is often severely limited in its effectiveness in low permeability* soil or bedrock due to :



- Low contaminant recovery rates
- Low injection volumes of treatment amendments
- Small radius of influence
- Large number of wells or injection points required
- Limited subsurface contact between contaminants and emplaced treatment amendments
- Limited carrying capacity of many treatment amendments
- Inability to verify subsurface distribution of amendments relative to contaminated zones

* $Kh < 1 \times 10^{-6}$ m/s

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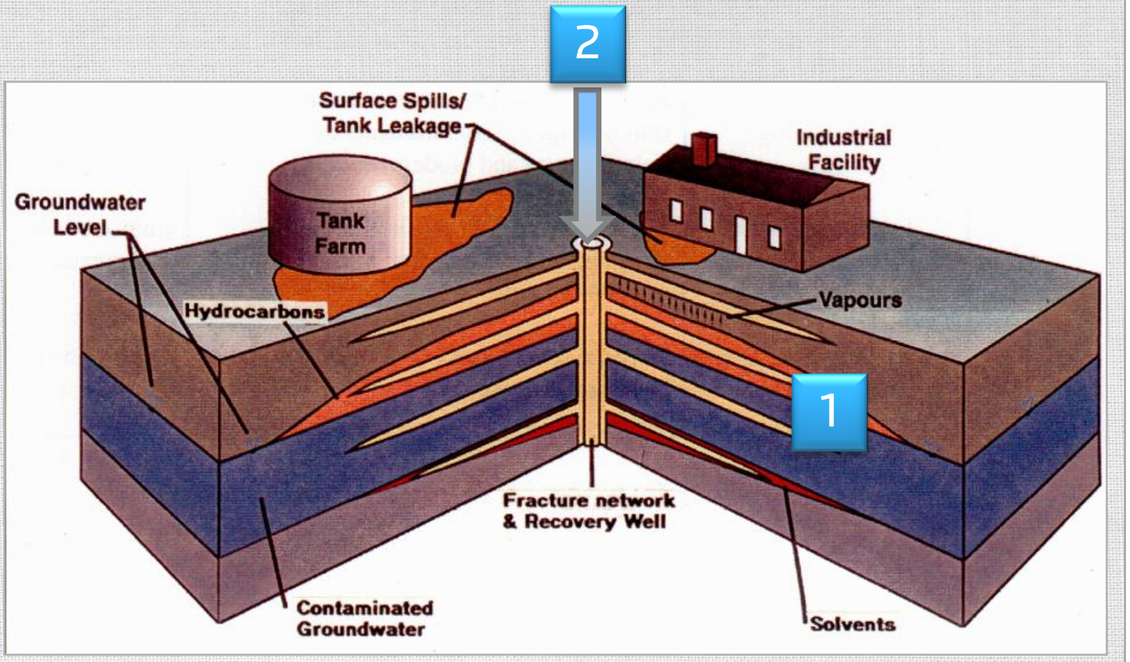
Improving in situ Remediation using i-SAV©

The i-SAV process creates a network of flow- and treatment pathways in contaminated sediments by the injection of slurries containing permeable substrates and/or treatment amendments



1. Permeable pathways hydraulicallý induced in soil or bedrock
2. Subsequent injection of amendments into subsurface flow network eg. Persulfates, Emulsified Oils, etc.

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i-SAV© Process applied on site

REQUIREMENTS:

- Drilling equipment
- Mixing & Pumping unit
- Fluid Viscosifiers
- Specialized downhole Injection tooling
- Operational Protocols
- Quality amendments
- Geophysical Mapping

i-SAV increases soil permeability and contact

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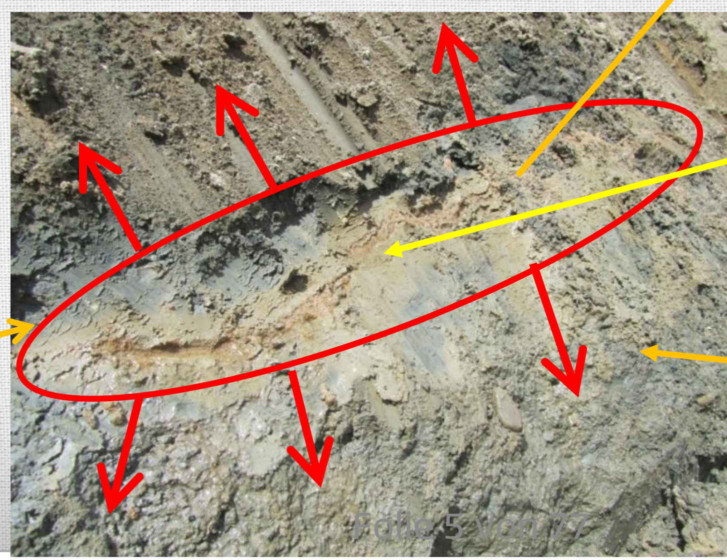
Permeable, sand filled flow pathways emplaced in a low permeability clay till.

Horizontal flow layer for the distribution of oxidant solutions



K sand:
1 x 10^{-4} m/s

Oxidant permeation into clay ± 15 cm after 2 months

K clay:
3 x 10^{-8} m/s

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Substrate Emplacement

High viscosity, water based carrier fluids allow for high concentration of amendment emplacement (up to 1 tonne/m^3).

The i-SAV© process utilizes drinking quallity water and food-grade thickeners (e.g. guar) to create slurries which are emplaced into subsoils.

ZVI

Chitin

Sand

Guar

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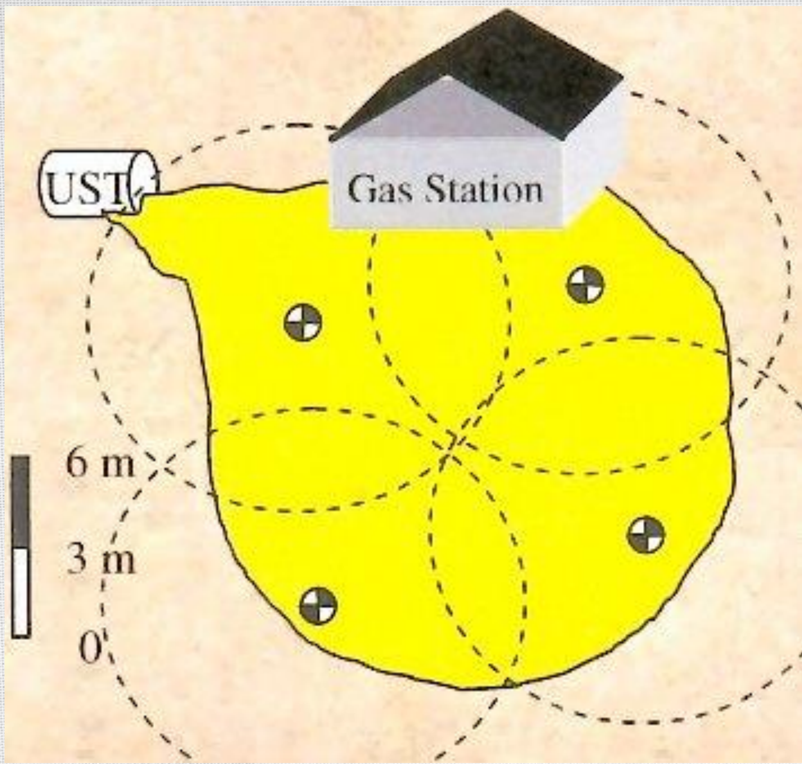
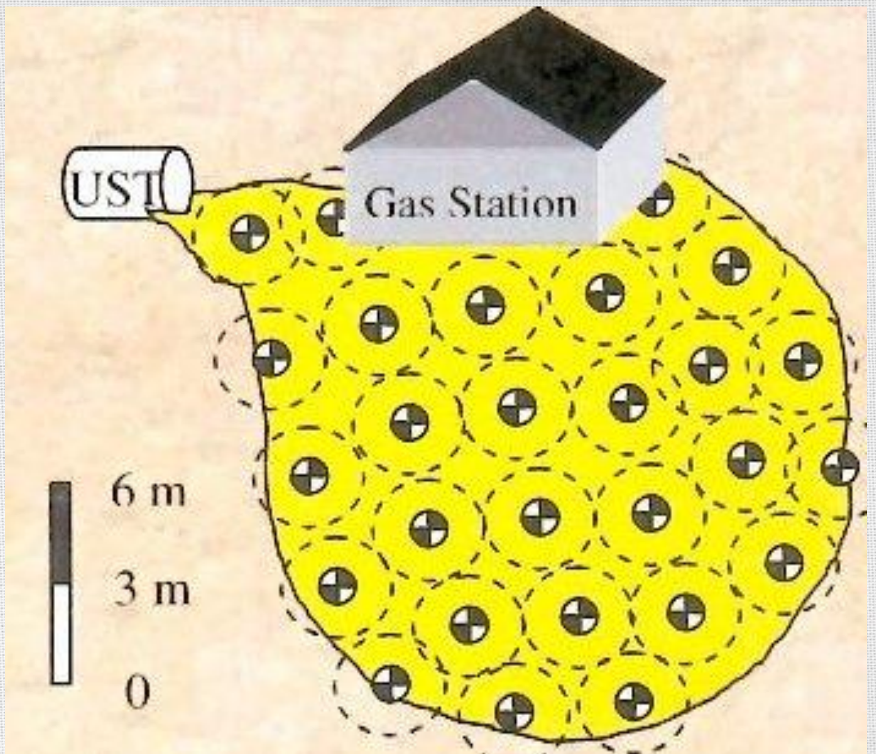
i-SAV© requires fewer wells





i-SAV hydraulic emplacement of amendments

Direct Push injection of amendments

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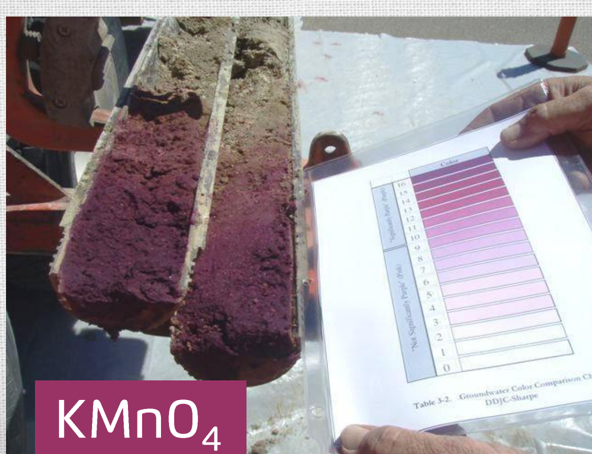
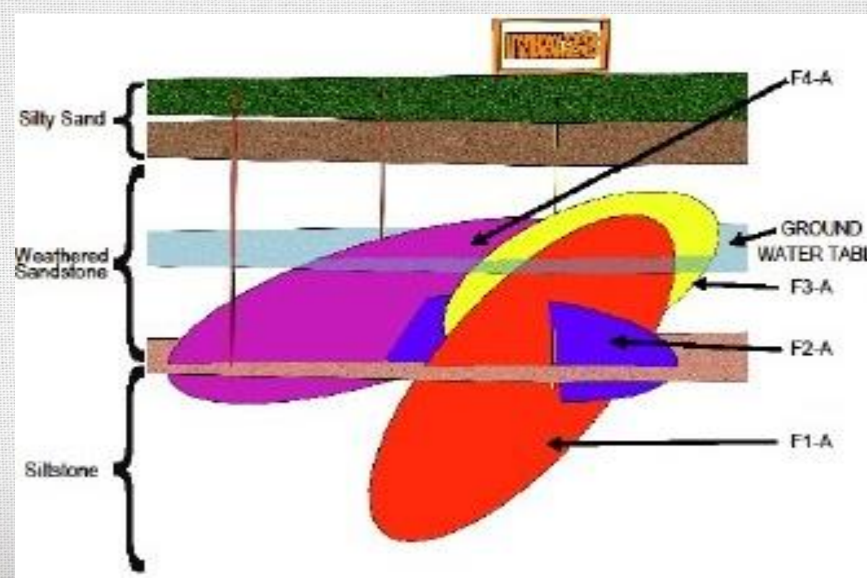
i-SAV© can verify the subsurface distribution of amendments emplaced into subsoils

Tiltmeter geophysics is effective in mapping the 3D distribution of flow pathways or amendments in the subsurface.





Over 25 years of Global Application

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- Industrial Manufacturing
- Military Installations
- Brownfield Redevelopment
- Tankfarms and Refineries
- Oil and Gas Producion Facilities
- Gasoline Stations
- Chemical Plants
- Dry Cleaning Facilities
- Logistics and Transportion
- Mining

EUROPE, NORTH AMERICA, AFRICA, ASIA

Case Study:

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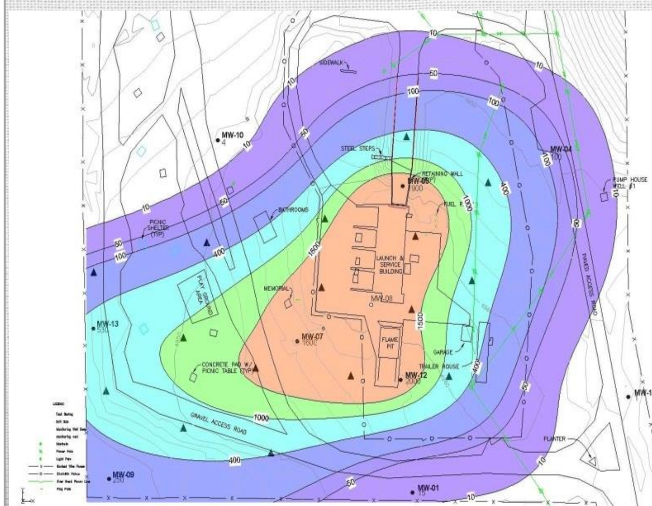
i-SAV© enhanced emplacement of ZVI into bedrock



<u>In situ chemcial reduction (ISCR) of TCE using a micro iron – cellulose carbon substrate, “EHC”</u>

BACKGROUND:

- Former US Airforce “Atlas 12” Missile Base Site
- Suspected leakage of TCE (1960-1965)
- Depth of TCE impacts into aquifer (25m bgs)
- Widespread area of TCE distribution.
- TCE Concentration upwards to 4,000 µg/L

ISCR: In situ chemical reduction
TCE: Trichloroethylene
ZVI: Zero valent Iron

TCE Source Area Treatment in Bedrock Sediments

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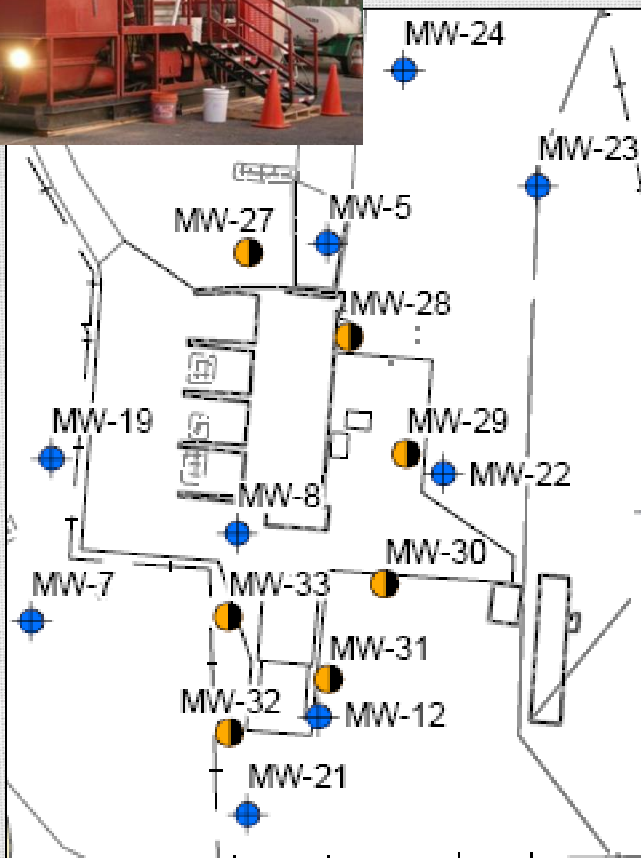

= Boreholes with ZVI emplacment

- Boreholes drilled to 25m depth into "Foxhill Sandstone" Formation
- ZVI comprising micro-iron and soluble carbon ("EHC") hydraulically emplaced into bedrock between 15 to 25m using dual packer system
- Radius of ZVI distribution > 20 m
- Mass of ZVI Emplaced into 9 Borings: > 100 Tonnes injected at 63 depths

ISCR: In situ chemical reduction
TCE: Trichloroethylene
ZVI: Zero valent Iron

Subsurface Distribution of ZVI

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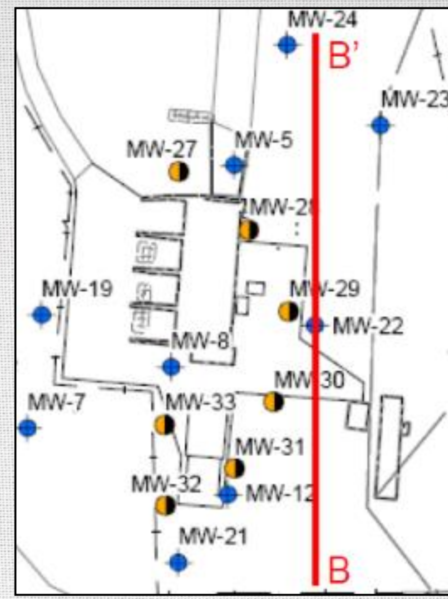
Tiltmeter Geophysical Mapping of ZVI:

- Plan View (right)
- Cross Section (below)

Confirms interconnected distribution of ZVI to act as a long term PERMEABLE REACTIVE BARRIER (PRB)

Length: 150 m, Height: 25 m, Width: 50 m



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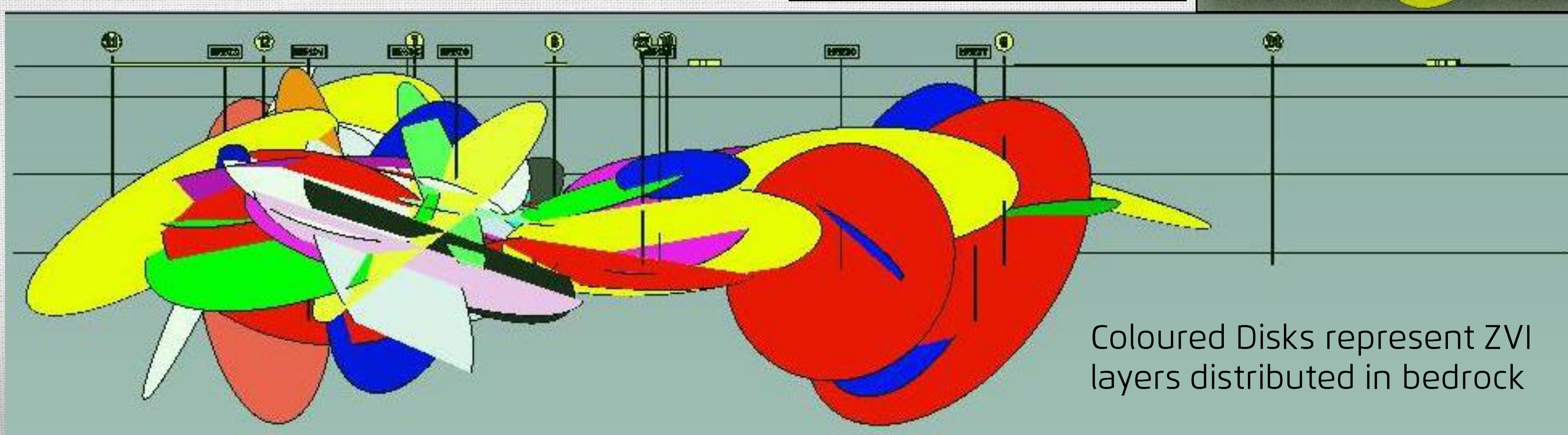

Results

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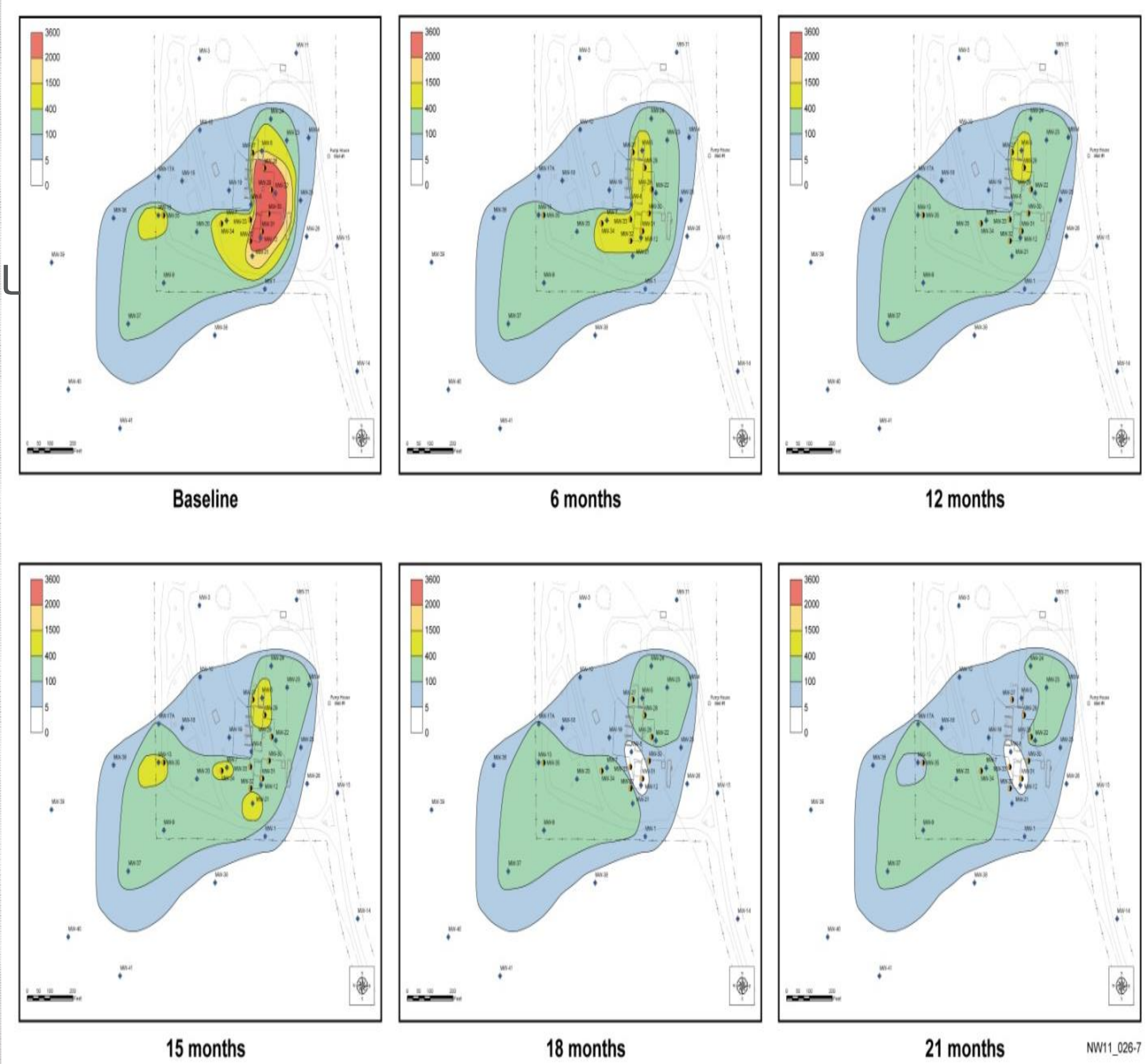
Source Area:

- Initial TCE Conc.: > 2,000 – 4,000 µg/L
- After 12 Months: < 400 µg/L
- After 21 Months: <100 µg/L

Distal Plume Area:

- Initial TCE Conc.: 500 - 700 µg/L
- After 21 Months: 200 - 400 µg/L



TCE Removed

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Phase 1: Injecion of 100 t ZVI

Source Area Plume:

94% <100 µg/L TCE (RMC)

Distal Plume :

82% < TCE RMC

Phase 2: additional 40 t ZVI injected

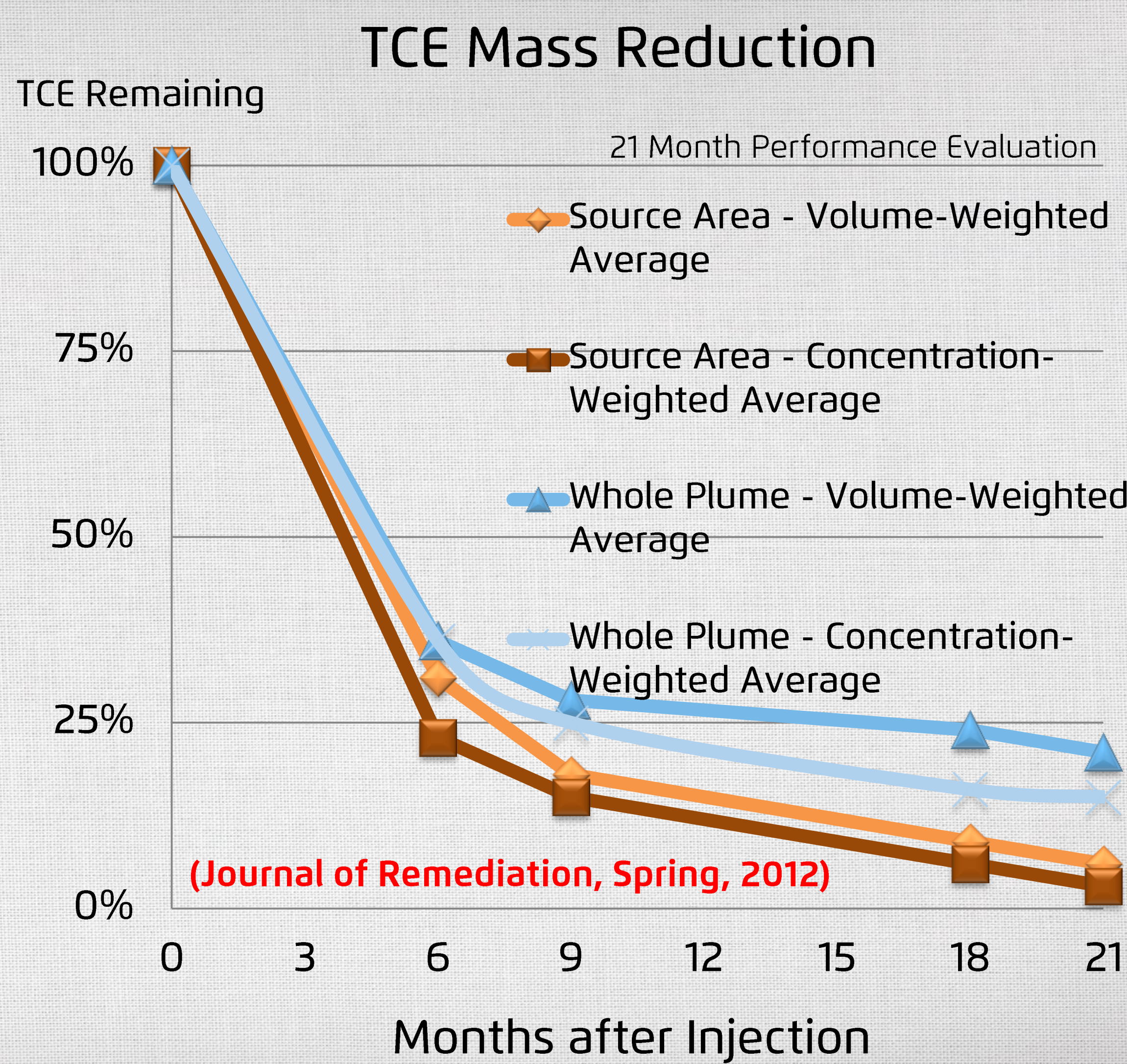
Source Area Plume:

TCE- Conc.: n.d. – 100 µg/l

Cost of Treatment:

8 $/t

→ Accepted as an innovative approach for missile base remediation by US DOD.



Case Study:

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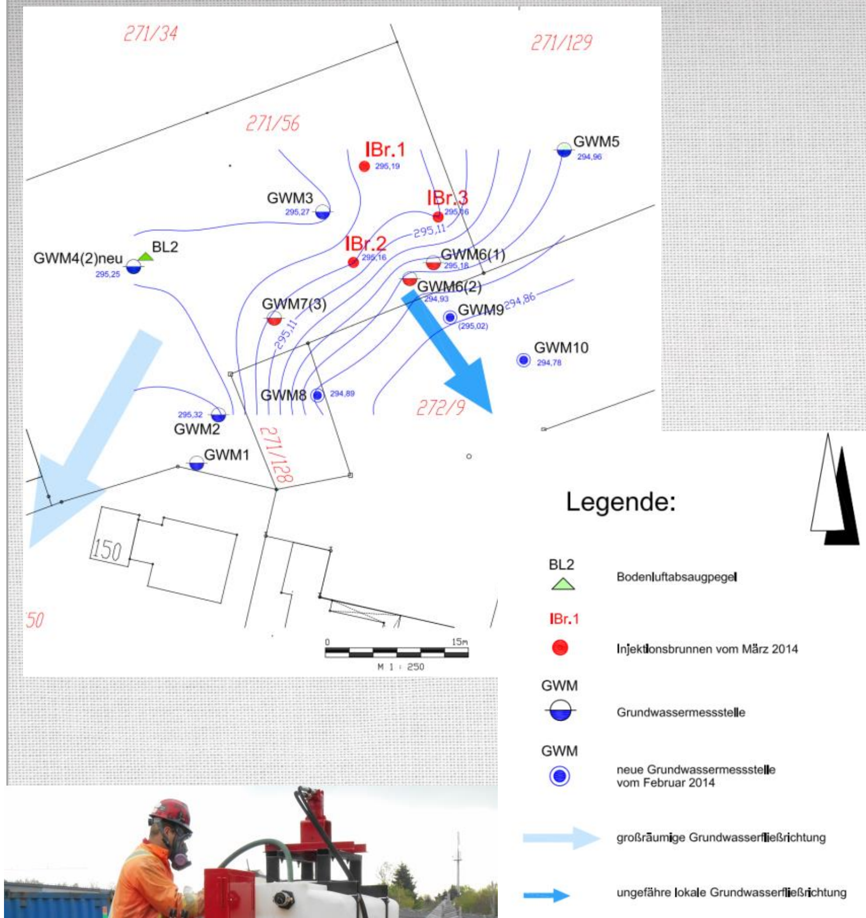
i-SAV© enhanced In Situ Chemical Oxidation (ISCO)

- Former Industrial Property in Germany
- Contamination from CVOCs and BTEX in the former storage tank area
- Contaminant impacts present in low permeability Blasensandstein (sandstone) to a depth of 12 m bgs
- Pump & Treat not deemed practical and excavation not possible
- Preferred approach was hydraulically emplacement of oxidant slurry as distinct layers in affected bedrock

i-SAV enhanced ISCO



PILOT PROGRAMME:

- Pilot work was focused in source area of plume and targeted the most heavily impacted groundwater unit from 7 to 11 m below ground surface.
- Potassium persulfate was formulated as a slurry and propagated from 15 pre-determined depths into bedrock from 3 seperate boreholes (i.e. 5 injection points per borehole)
- 1,350 kg of $K_2S_2O_8$ with 200 kg of iron lactate activator were propagated over a radial distance of 6 m from each borehole

i-SAV enhanced ISCO

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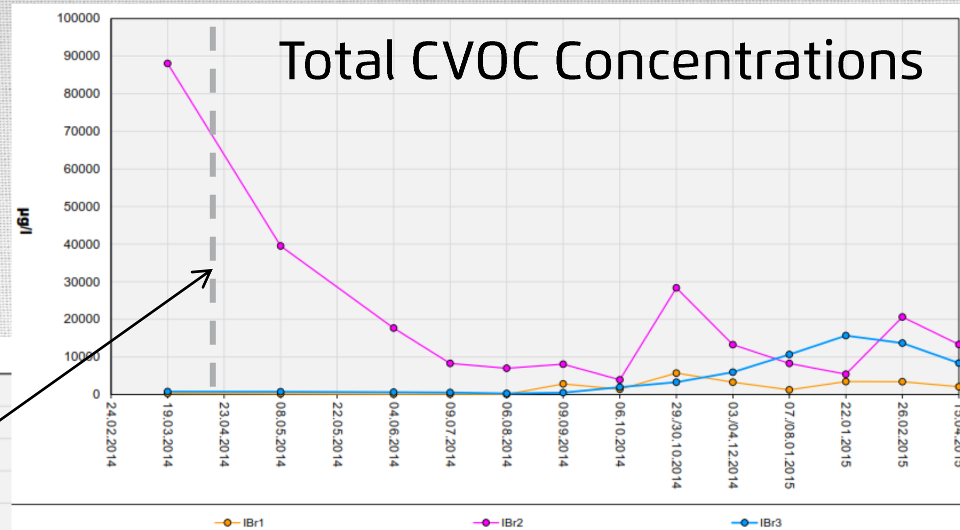
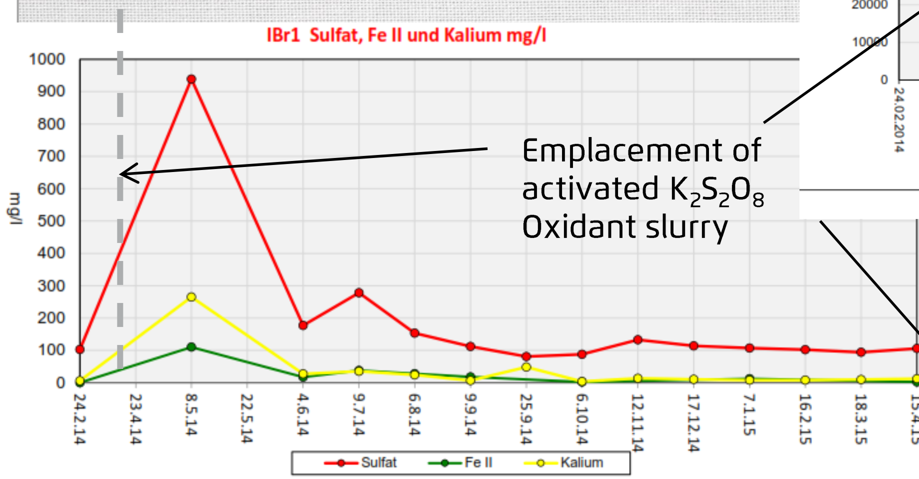
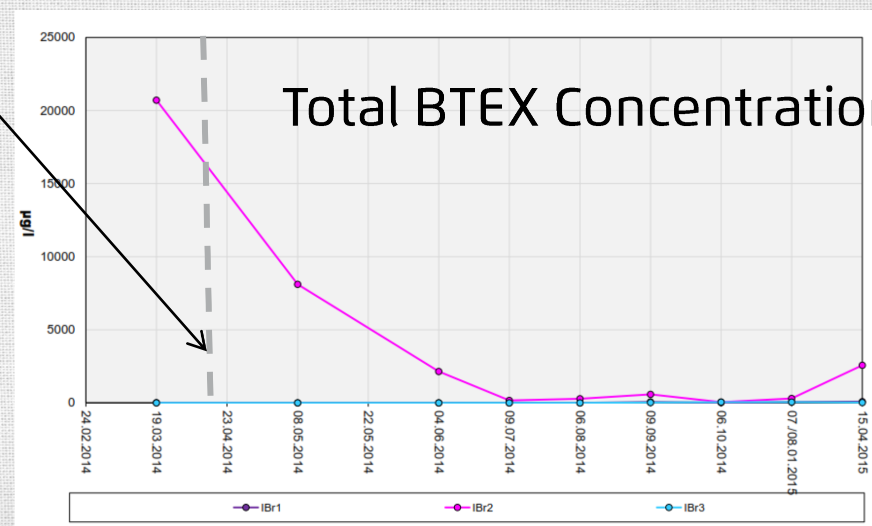
Analytical Results: Source Area





Emplacement of activated $K_2S_2O_8$ Oxidant slurry



Sulfate, Fe2+ Iron, and Potassium Concentrations

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Results

After 12 Months:

- Successful hydraulic emplacement and distribution of Oxidants across a 200 m² area using only 3 Boreholes
- Potassium persulfate caused a significant decrease in contaminant mass remaining, upwards of 99% total contaminants oxidized
- Subsequent anaerobic microbial degradation of contaminants followed using residual sulfate as electron acceptor

Table 1:

Contaminant Concentrations before and after Persulfate emplacement in IBr.2

	PCE µg/l	TCE µg/l	cIs DCE µg/l	BTEX µg/l	PAH µg/l
Pre-treatment Concentrations					
19.03.2015	13,000	22,000	52,000	20,713	98.39
6 Months after Persulfate emplacement					
07.10.2014	8.1	23	3,800	47	5.45
Decrease in %	99.94	99.90	92.69	99.77	94.46
12 Months after Persulfate emplacement					
15.04.2015	4.3	6.4	13,000	2,570	103.6
Decrease in %	99.97	99.97	75.00	87.59	minor Backdiffusion -5.29

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i-SAV Advantages

- Significantly enhanced subsurface permeability
- Significantly increased contact area with contaminants
- Large radius of influence & distribution (> 20 m!)
- Fewer boreholes and wells required
- In situ construction of PRBs possible
- Small footprint – ideal for operational plant sites
- No excavation necessary
- Works synergistically with other remedial technologies, e.g. pump and treat, SVE, MPE
- Simultaneous emplacement of treatment amendments
- Cost savings


EHC Slurry in Subhorizontal Fractures
1-1.5" Apart at 54 Feet BGS

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SUMMARY

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The ability to create flow pathway networks improves subsurface permeability and contact with contaminants. The i-SAV process thus helps to overcome the traditional limitations of in situ remediation, particularly in challenging soil and bedrock conditions:

- Cost-effectively
- Verifiably
- Sustainably, and
- Synergistically

… to your Advantage!!

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CONTACT FOR FURTHER INFORMATION:

Gordon.bures@riskcom.de
+49 (0) 152 3425 2949
Leipzig, Germany
www.riskcom.de

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