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CONTAMINATED SITES 2022

SENEC, SLOVAK REPUBLIC, 12 – 14 OCTOBER 2022

*The activity has been implemented within the framework of national project
Information and providing advice on improving the quality of environment in Slovakia.
The project is cofinanced by Cohesion Fund of the EU under Operational programme Quality of Environment.*

Full-scale Application in Italy of EHC[®] Liquid technology: Combined ISCR and ERD treatment of an Aerobic Aquifer impacted with Tetrachloromethane and Chloroform

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Agenda

- *Evonik Operations GmbH* Overview
 - Our approach to working with customers, typical services we provide
- Discussing your interests and needs
- Review of selected technologies, application types, EHC-Liquid case study
- Discussion, thoughts, and follow up

It's Official !

PeroxyChem, LLC USA is now

.....
Evonik Operations GmbH, DE



Evonik Soil & Groundwater Remediation

remediation@evonik.com

www.evonik.com/remediation

Technical Expertise and Support

- Multidiscipline Team of Experienced Environmental Professionals
- Team of MS, PE, PhD level scientists
 - Recognized and published subject matter experts



- Conceptual Approach, Budget
 - Design Considerations
- Remedial Goals
 - Application Guidance
- Safety and Handling
 - Baseline and Monitoring recommendations
- Post application support

Supporting the successful application of our products

Laboratory Services

- Bench Testing Purpose and Benefits:
 - Develop engineering parameters for field application
 - Confirm treatment efficacy with one or multiple treatment technologies
 - Lower cost and risk compared to evaluation in the field
 - Can refine cost estimates during a feasibility study

- Treatability Testing for all Products
 - Column and Batch
 - MetaFix Screening Test - Low Cost 3000 EUR
 - Klozur Persulfate
 - Klozur Demand Test
 - Total Oxidant Demand Test
 - Base Buffering Capacity



Technical Resources

- Webinars
 - Library on peroxychem.com/remediation for on demand viewing
 - Subscribe for email notifications
- Case Study Library
 - Filter by product, contaminant, key word search
- Technical Documents Library
 - SDS
 - Product Application Guides
 - Technical Bulletins

www.peroxychem.com/remediation

The screenshot displays the website's navigation and content areas. The top navigation bar includes 'Home / Environment / Soil and Groundwater / Webinars'. The 'Webinars' section features a list of topics such as 'Introduction', 'Soil Mixing', 'PFAS Emer', 'Monitoring After an Acc', 'In Situ Treat', 'Heavy Met', 'Bench Test', and 'Design Con'. The 'Case Studies' section highlights 'EHC® Reagent for Tre' and 'In Situ Reductive Remediation Technology Overview'. The 'Technical Documents' section lists various guides and reports, including 'The Kloxur® Activator Selection Guide', 'Kloxur® CR: Combining Chemical Oxidation with Bioremediation', 'Kloxur® KP Technology Overview', 'Enhancing Reductive Dechlorination', 'Assessment Report of Sustainability of Green Remediation Technologies', 'Kloxur® Persulfate: The Impact of Sulfate Residual', and 'Guidelines for Kloxur® Persulfate Alkaline Activation'. A search bar and filter options are visible on the right side of the page.

Our Approach

Site Evaluation

Cost Effective Solutions for Your Site

SITE INFORMATION / ASSUMPTIONS	Value	Unit	Notes
Area of Treatment	0	m ²	customer input
Treatment Zone Thickness	0	m	customer input
Treatment Volume	0	m ³	customer input
Permeability	30	%	customer input
Drilled Water Volume	0	m ³ /day	customer input
Soil Density	1.6	g/cm ³	customer input
Soil Moisture	0	%	customer input
Proposed Soil Mass Concentration	100	%	customer input
Groundwater volume			
Soil bulk density			
Soil mass			
Transport characteristics:			
Treatment zone design life for one application			
Linear groundwater flow velocity			
Distance of inflow over design life			
Effective porosity for groundwater flow			
Volume of water passing region over design life			

Customer Provided Site Information:

- Contaminant Information
- Geochemical Data
- Hydrogeology/Geology Information

Initial Product Demand Estimate:

- Product Overview
- Volume
- Pricing
- Packaging Options
- General Handling Guidance

www.peroxychem.com/remediation

Evonik Soil & Groundwater Remediation

Field-Proven Portfolio of Remediation Technologies

Chemical Oxidation

- Klozur® Persulfate Portfolio
 - Klozur® SP
 - Klozur® KP
 - Klozur® One
 - Klozur® CR
- Hydrogen Peroxide

Aerobic Bioremediation

- Terramend® Reagent
- PermeOx® Ultra
- PermeOx® Ultra Granular

Metals Remediation

- MetaFix® Reagents

Chemical Reduction

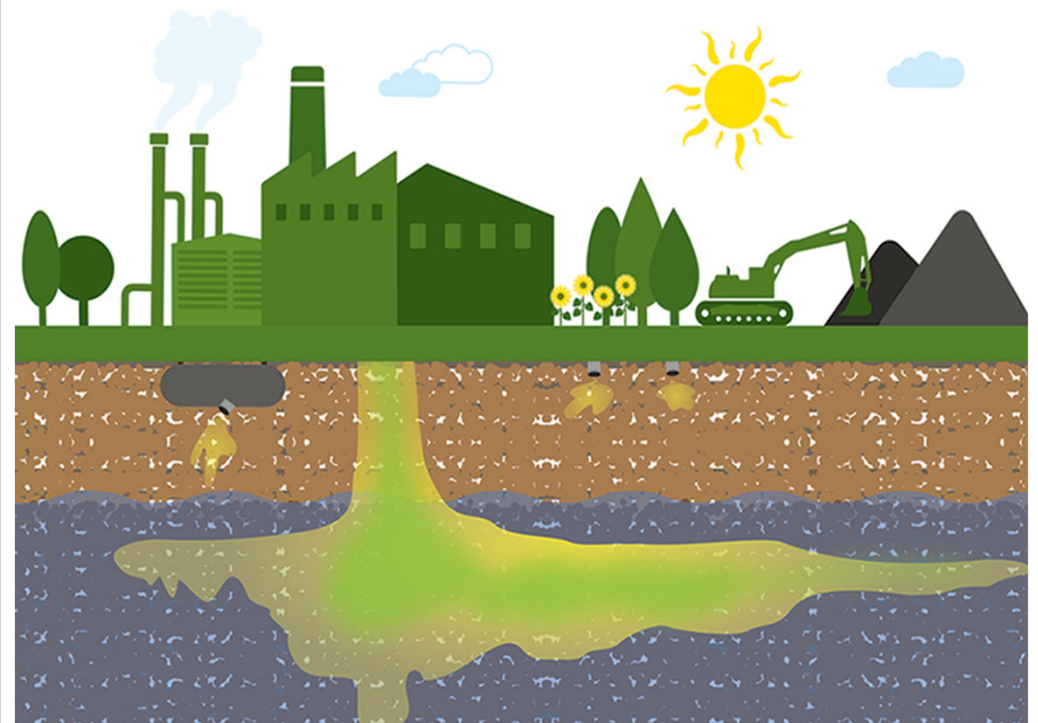
- EHC ISCR Portfolio
 - EHC® Reagent
 - **EHC® Liquid**
 - EHC® Plus
- Daramend® Reagent

Enhanced Reductive Dechlorination

- ELS® Microemulsion
- ELS® Liquid Concentrate
- ELS® Dry Concentrate

BioGeoChemical

- GeoForm™ Reagents



Contaminants Treated



Petroleum Hydrocarbons

Phenols

Chlorinated Solvents

Heavy Metals

BTEX

Oxygenates

Energetics

Pesticides & Herbicides

PAHs

Chlorobenzenes

PCBs

Fluorinated Compounds

1,4-dioxane Arsenic

Products

PermeOx[®]
Ultra

Terramend[®]
Reagent

KLOZUR[®]

EHC[®] Liquid
EHC[®] Reagent

ELS[™]
Microemulsion

Daramend[®]
Reagent

METAFIX[®]
REAGENT



Reductive Technologies



Evonik offers a full suite of Reductive Technologies

Leading the way in developing reductive remediation technologies for nearly 30 years

Reductive Treatment of Organic Contaminants

Biological treatment

- Apply organic substrate (electron donor; e.g., ELS)
- Bacteria transfer electrons from the donor to the acceptor to reduce the oxidized contaminants to non-toxic chemicals.
- Bacteria use reduce the oxidized contaminants to less soluble reduced chemicals (e.g., Chromium [VI])

Abiotic treatment

- Apply an inorganic reduced chemical (e.g., ZVI,).
- Relatively oxidized contaminant is reduced to non-toxic end products by contact with reduced chemical.
- Relatively oxidized soluble is reduced to a less soluble metal (e.g., Cr[VI] to Cr[III])




Biogeochemical treatment

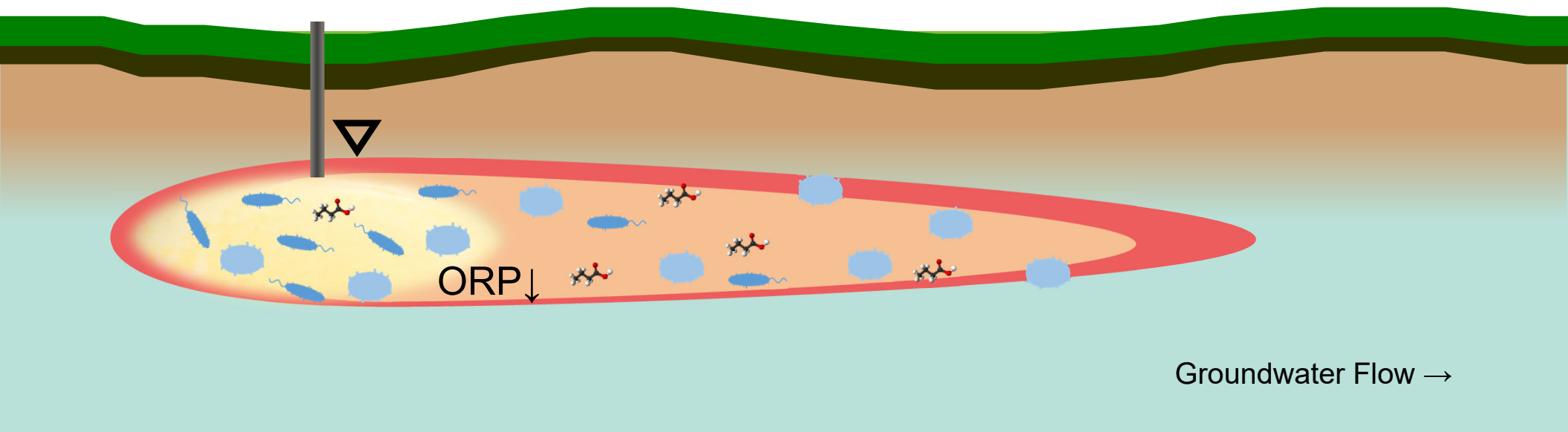
- Apply organic substrate (e.g., ELS) and an inorganic electron acceptor (e.g., sulfate) (e.g., Geoform Reagents)
- Bacteria use organic substrate to reduce the inorganic electron acceptor creating a reactive reduced mineral (e.g., pyrite (FeS_2))
- Relatively oxidized contaminant is reduced to less bioavailable chemical by contact with reduced mineral.
- Relatively oxidized soluble contaminant is reduced to a less soluble chemical (e.g., Cr[VI] to Cr[III]) or by combining the metal with a reduced ion (e.g, arsenic/arsenopyrite).

Overview of Reductive Mechanisms

Enhanced Reductive Dechlorination

After the addition of organic carbon (liquid or solid) to the subsurface:

-  Heterotrophic bacteria feed on the organic carbon as an electron acceptors reducing the redox potential
-  Volatile fatty acids (VFAs) are generated through fermentation and released into the treatment area
-  Dehalogenators utilize the VFAs as electron donors and feed on the chlorinated organics



Overview of Reductive Mechanisms

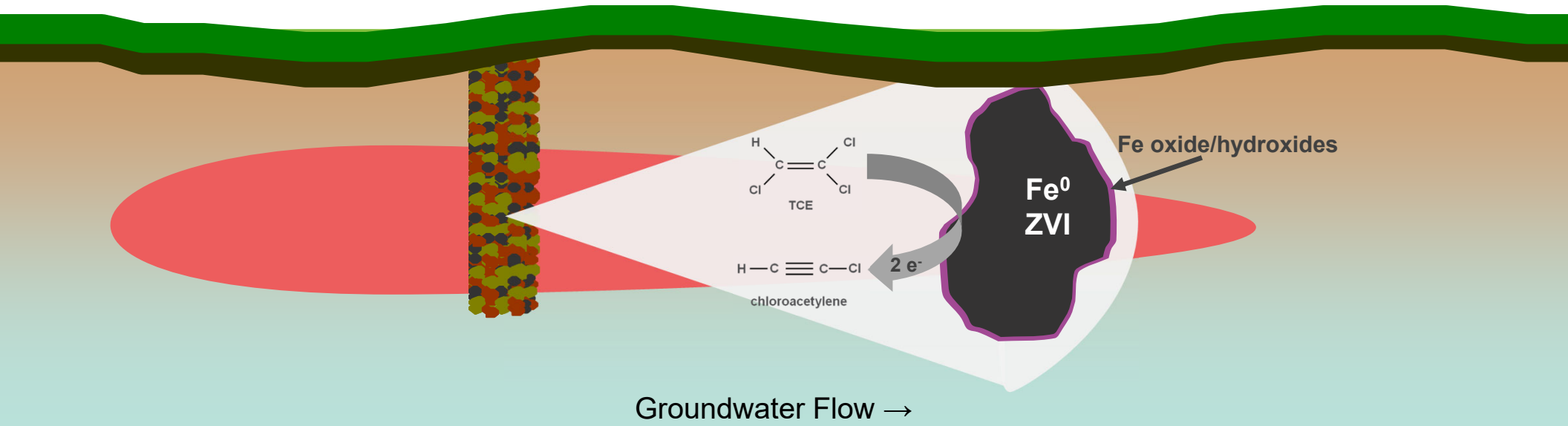
Direct Chemical Reduction

A **redox** reaction occurs when there is direct contact with ZVI and halogenated contaminants

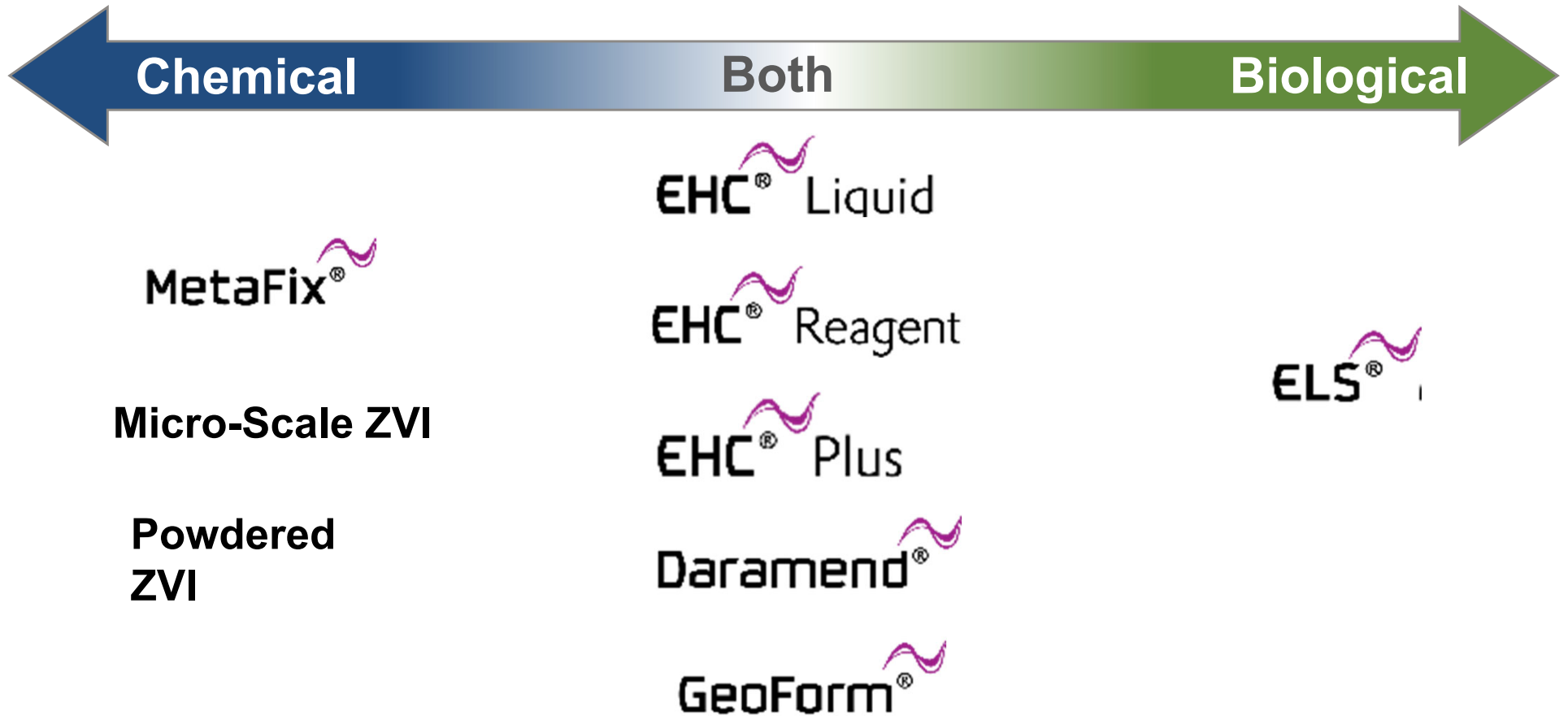
Reduction: ZVI can offer up 2 electrons for dechlorination or reduction of the halogenated contaminants

Oxidation: ZVI takes on oxygen to form Fe(II) or Fe(III) corrosion products on the surface of the ZVI

- A source of organic carbon can help abate the passivation of ZVI

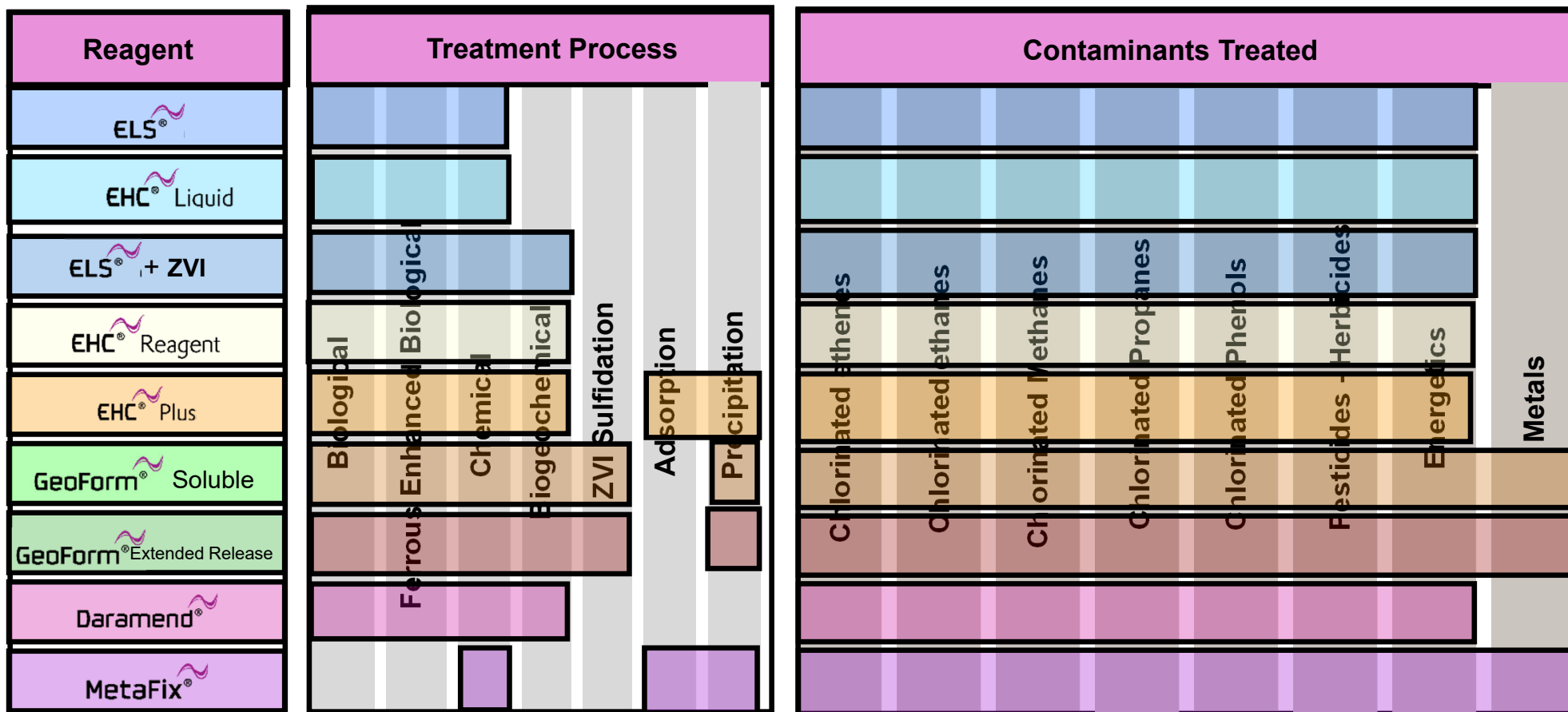


Reductive Technologies



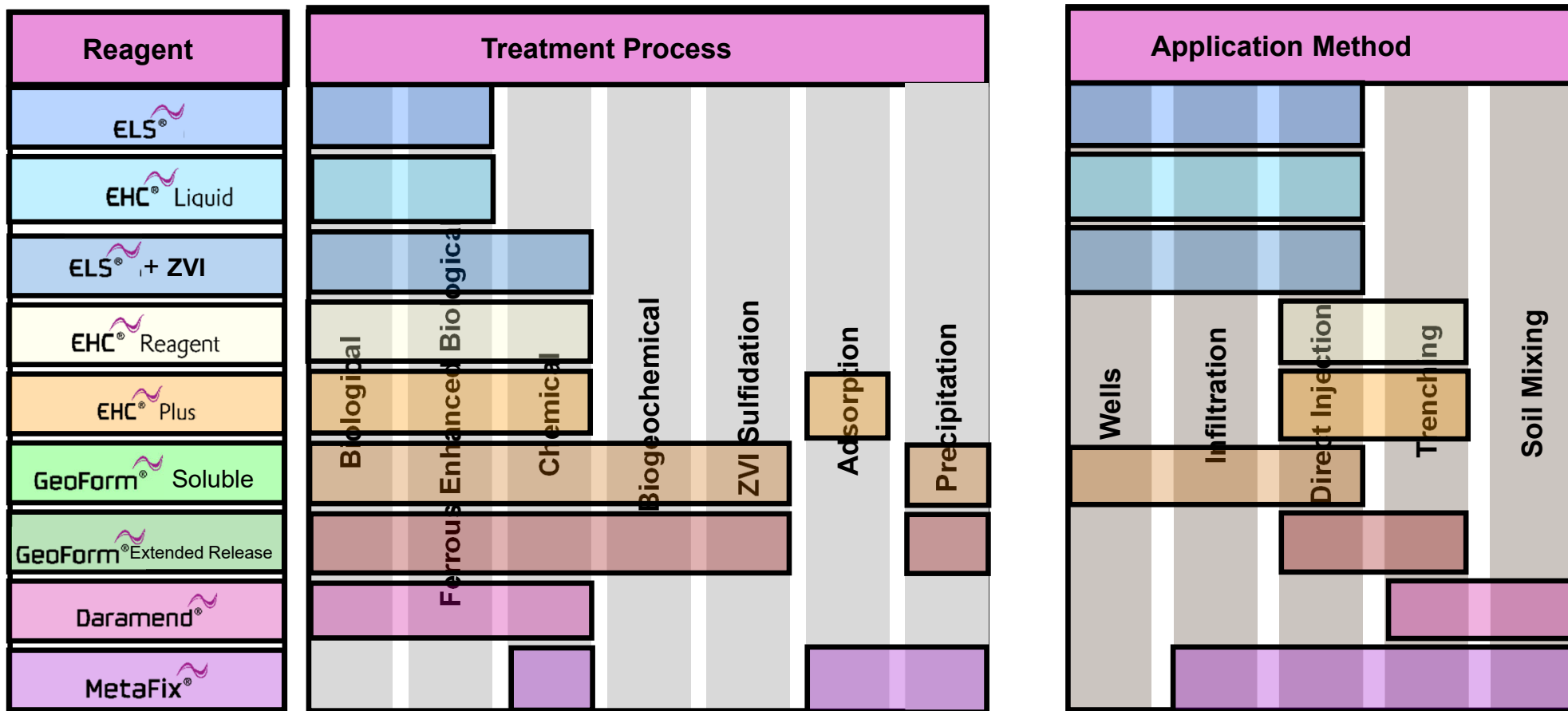
Evonik Soil & Groundwater Remediation

Field-Proven Portfolio of Reductive Remediation Technologies



Evonik Soil & Groundwater Remediation

Field-Proven Portfolio of Reductive Remediation Technologies



EHC[®] Liquid Overview

- Cold-water soluble ISCR product - injection via existing wells or hydraulic injection networks
- Composition - controlled-release organic carbon with an organo-iron compound - all food grade
- Delivered in two parts:
 1. ELS[®] Microemulsion or Concentrate
 2. EHC[®] Liquid Mix, an organo-iron powder.
 - pH buffer, if needed, delivered as powder
- Water content will vary with desired injection volume and physical conditions

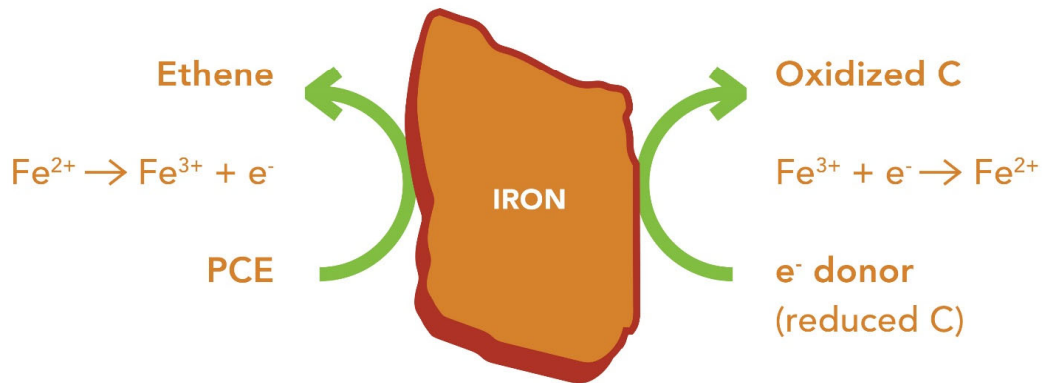


EHC[®] Liquid Key Benefits

Fully soluble reagent promoting both Enhanced Reductive Dechlorination and Indirect Chemical Reduction

ISCR reactions of Fe²⁺ with chlorinated contaminants and formation of Fe³⁺

Bacterial extraction of electrons from carbon restore Fe³⁺ to Fe²⁺ (Fe³⁺ is the e⁻ acceptor)

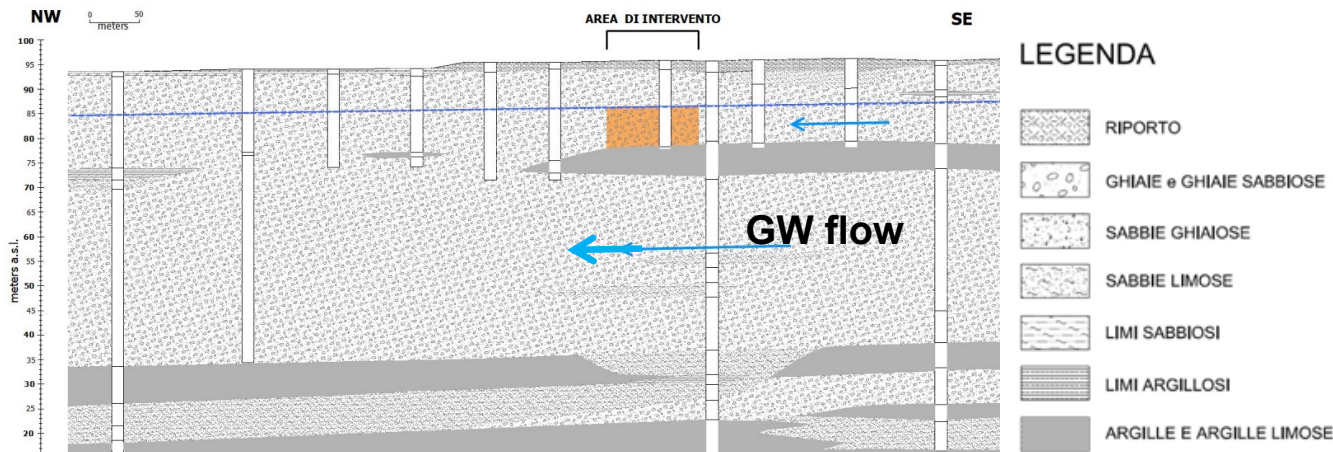


■ Composition

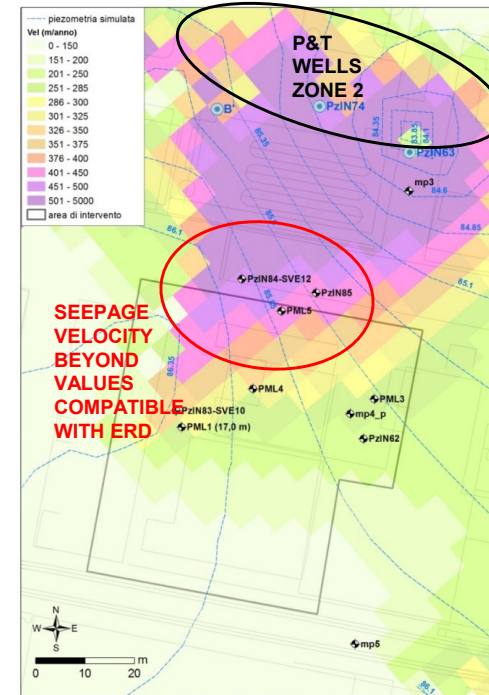
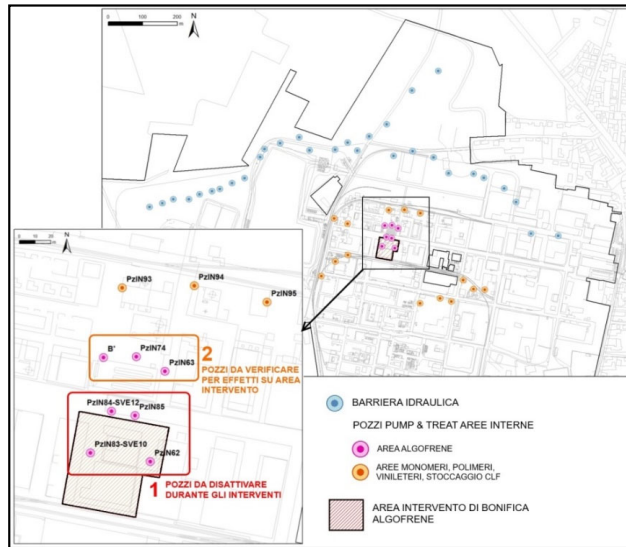
- ELS Microemulsion (25%) or ELS Concentrate (100%)
- EHC Liquid Mix is soluble organo-iron powder (added to ELS emulsion in the field)

Field Case Study – Italy

- Active Chemical plant with numerous facilities
- Treatment area: **> 2.250 m²**
- Treatment area thickness: **9 m**
- GW table: **8 m bgl**
- Saturated soil matrix: **gravelly sand**
- Seepage velocity \approx **280 m/yr**
- GW natural geochemical conditions: **Aerobic, neutral pH**
- COCs: **CT > 5 mg/l, CF > 3 mg/l, TCE > 0.5 mg/l, CrVI > 2 mg/l**
- Cleanup goals: **Regulatory limits (CT = 0.066 mg/l, CF = 0.065 mg/l)**



Verifying P&T Effects on EHC-Liquid Treatment Area...

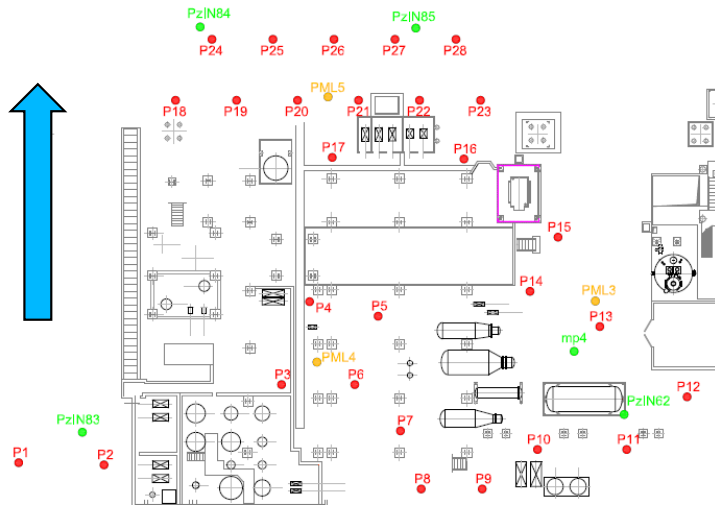


To protect effectiveness of the ERD treatment, it was necessary to switch off active P&T wells in Zone 1, located in the injection area.

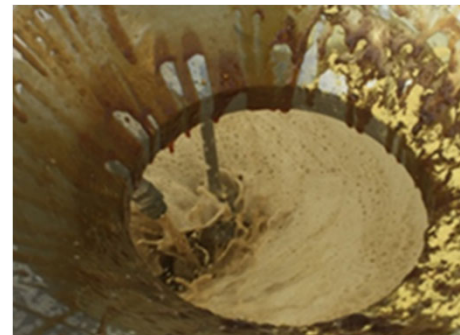
Effective ROI of the P&T wells located in Zone 2 was verified using MODFLOW2000 (USGS); a mathematical flow model.

Results of the model showed how wells located in Zone 2, at current flow rates, could have modified local groundwater flow conditions, causing an increase in flow velocities beyond values compatible with the ERD treatment design (300 meters/year).

ISCR / ERD Field Activity

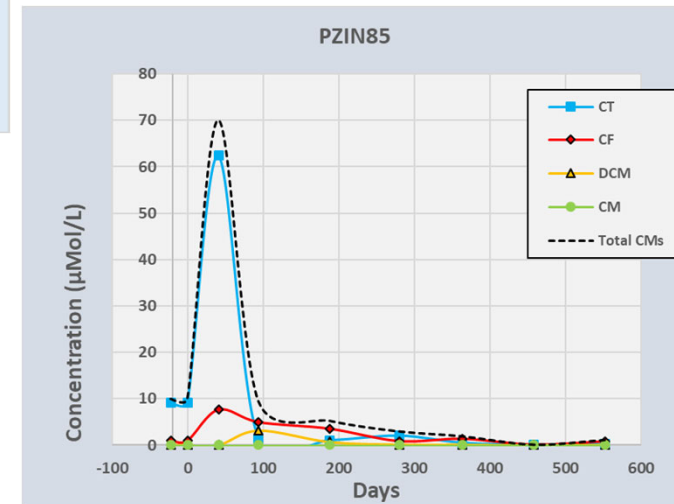
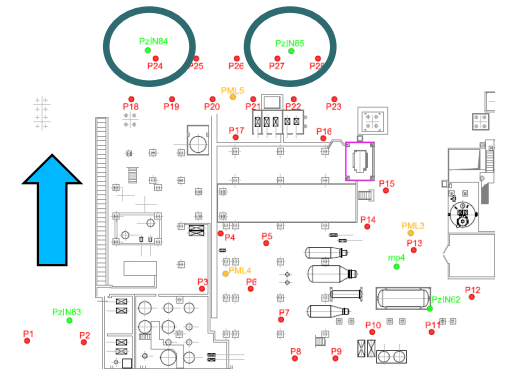
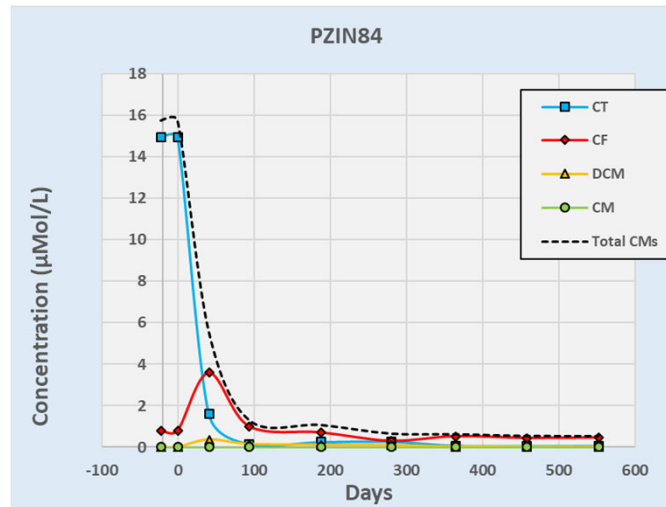
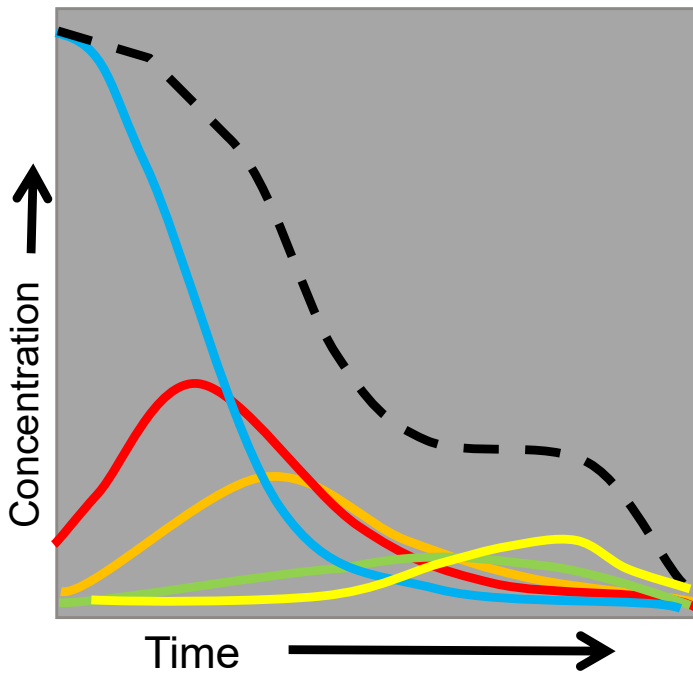


- **Application: Direct injection through 28 fixed Manchette tubes**
- **Injection campaign \approx 306 kg of ELS® Concentrate per point, plus 70 kg of organo-iron powder**
- **Total injection volume: 96 m³ of EHC® Liquid emulsion, in 10% solution**
- **Average injection pressure: \approx 17 Bar**
- **Average injection flow rate: \approx 17 L/minute**
- **Field activities start date: December 2017**
- **Plume Hydraulic control: Pump & Treat**

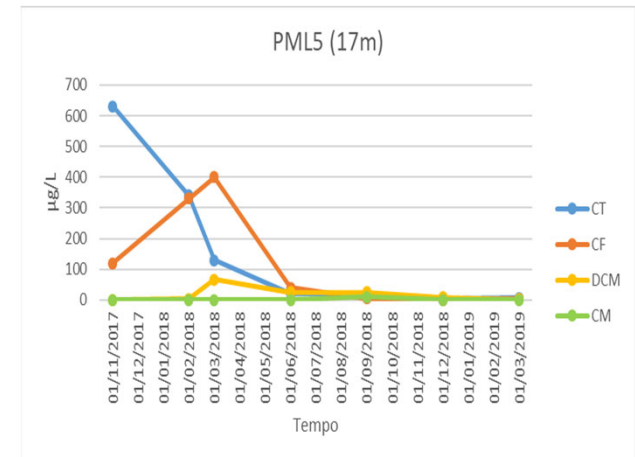
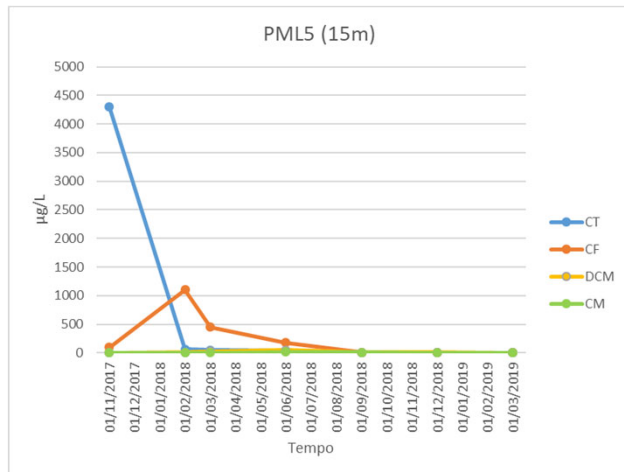
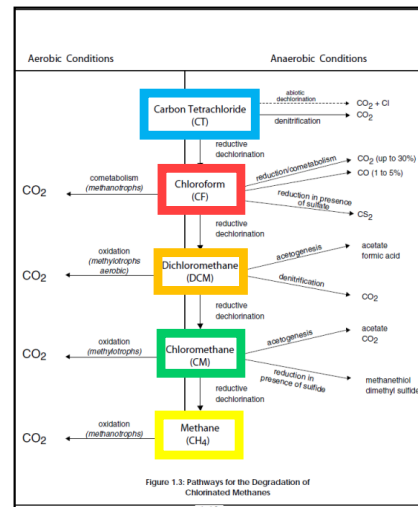
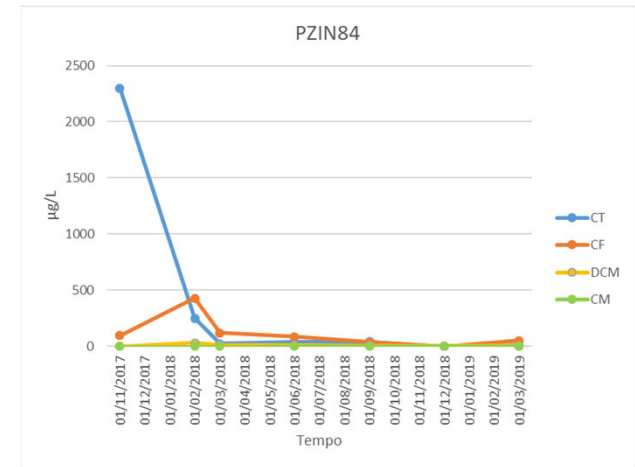
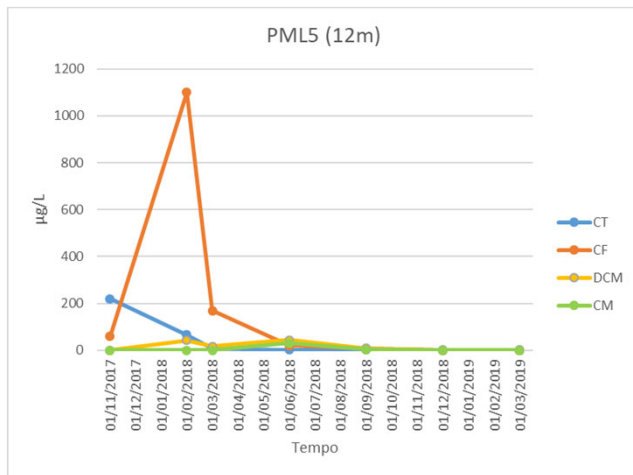


Post-Application Results (18 months) in $\mu\text{Mol/L}$

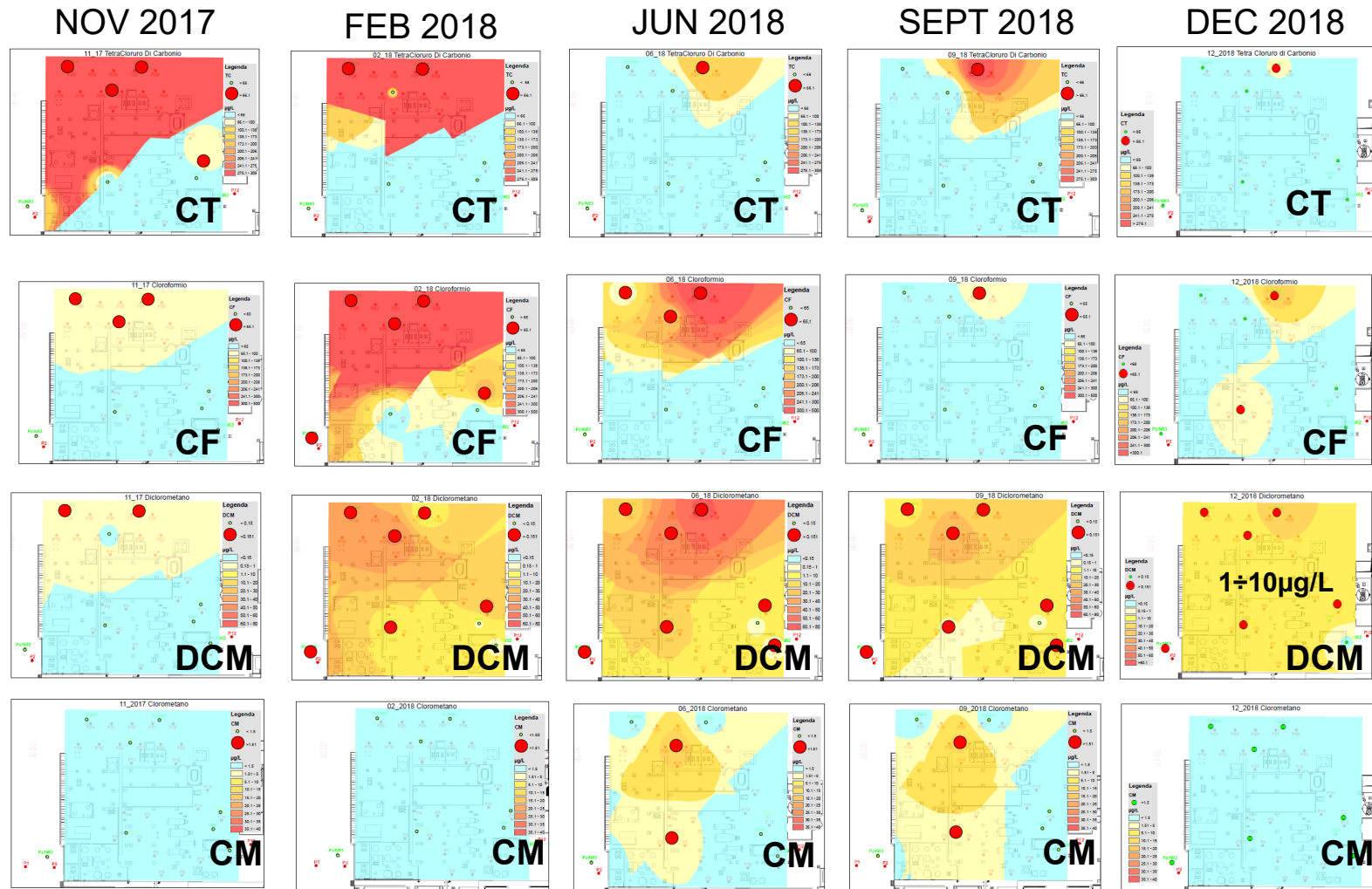
ISCR & ERD Degradation Performance Curves



Post-application results (15 months) in $\mu\text{g/L}$



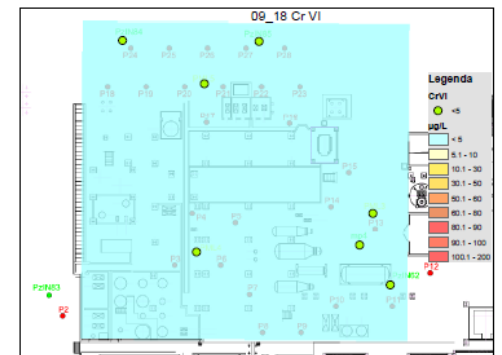
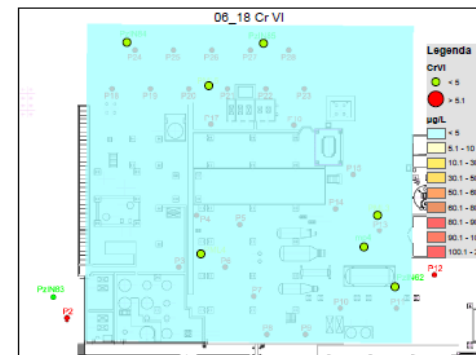
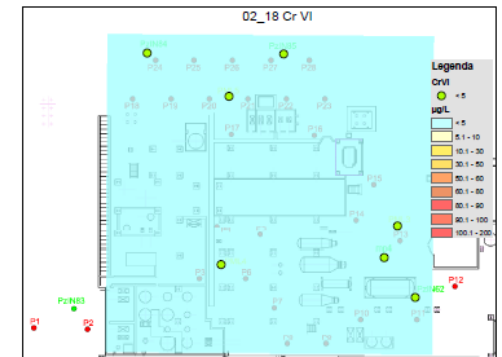
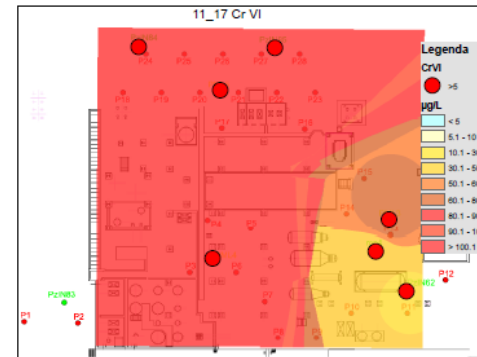
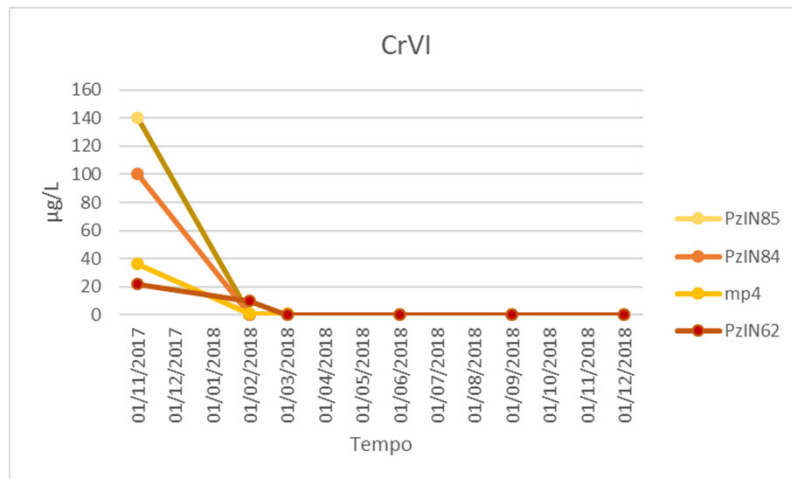
Post-application results (12 months) in $\mu\text{g/L}$



Post-application results (12 months) in $\mu\text{g/L}$

Main field parameters in the ISCR & ERD treatment areas:

- Increase of Mn & Fe(II) in solution as **anaerobic cometabolites**
- Decrease of DO (mg/L) and sulphate (mg/L) – **competing electron acceptors**
- pH stable in the **neutral range**
- **Negative Redox** around -50 to -150 mV



Summary of Evonik Reductive treatment Technologies

- Evonik Soil and Groundwater Solutions provides a wide range of reagents for reductive treatment of contaminants.
- Reagents apply proven remedial processes including biological, biogeochemical, and abiotic reduction as well as adsorption and precipitation
- Reagents are available for a variety of application methods such as injection and recirculation wells, high-pressure injection, trenching, soil mixing.
- Reagents are designed for treatment most organic and inorganic contaminants
- Reagents are composed of food-grade products and safe to use.
- Remedial products are produced by and enhance sustainable processes.
- Evonik provides supplemental products, e.g., buffers, dechlorinating cultures) to optimize remedial processes.
- Evonik's reductive reagents have been successfully applied demonstrated at thousands of sites around the world.

In Closing

- Thoughts or questions?
- Nest Steps
 - Capabilities resonate?
 - Any problem sites in the past
 - Any sites you would like to discuss more



**Thank you for your attention
We look forward to working
with you!**



EVONIK

Leading Beyond Chemistry