









SLOVAK ENVIRONMENT AGENCY

is implementing an activity

INTERNATIONAL CONFERENCE CONTAMINATED SITES ZNEČISTENÉ ÚZEMIA MEDZINÁRODNÁ KONFERENCIA

**INTERNATIONAL CONFERENCE** 

# **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.

www.op.kzp.sk

www.minzp.sk

www.sazp.sk

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

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European Union Cohesion Fund





## 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



| October 14, 2022 | Full-scale Application in Italy of EHC® Liquid technology

## **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

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	Home / En	Aronment / Soll and	d Groundwater / Weibiners			
	Web	binars				
	As part of education	of our commitm anal webinars,	ment to the soil and gn led by individuals from	oundwater remediation market, we offer a series of free webinars. The n our experienced team of technical professionals, focus on a variety of		_
	topics o	n the science	Horne / Environment / Soll and	Groundweter / Case Studies	5 0 ·	
	<u> </u>	Introducinę Dr. Brant Smi	Case Studie Over the years, we hav	S e successfully treated thousands of sites impacted by hazardous contaminants around the	SEARCH Q	
			globe. To search our ca	se studies, please use the filters provided at the right or enter a search term such as type of site		
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	Г	Introducing	EHC® Resgent for Tree As featured in Remediati challenges included a lo	Technical Documents		SEARCH Q
	4	Dr. Brant Smi	EHC" ISCR Respect Chi	The Klozur® Activetor Selection Guide The Klozur® Activator Selection Guide is for guidance only. It is recommended that a suitable tre	atability study be	FILTER BY PRODUCT
	0	PFAS Emer	EHC <sup>®</sup> Treatment of Gr	performed to verify applicability to you specific contaminant and site conditions.		
		including PFC	Groundwater at a forme reduction (ISCR) technol	In Situ Reductive Remediation Technology Overview An overview of the different properties, mechanisms, and key attributes of our various reductive	technologies	All
		Monitoring After an Ap	EHC" ISCR Respect Chi	Klozur® CR: Combining Chemical Oxidation with Bioremediation		FILTER BY TYPE
		Dr. Brant Smi best practice	EPIC <sup>®</sup> PRB for Treatme The EPIC <sup>®</sup> PRB was instal installation the PRB is stil	An introduction of Nozurii CR, a single, tormulated product consisting of high pH-4-Chvated Koz PermeOxti Plus engineered calcium peroxide, Klozurii CR combines the speed and power of	ur® persulfate and	Klozur Activation Guide
	<u> </u>	In Situ Trea Dr. Alan Sees	EHC*ISCRAssgent Chi	Riozur® KP Technology Overview An in depth review of extended release potassium persulfate including the theory behind the ex recommended doxing and potential applications.	tended release,	Safety Data Sheet  Technical Bulletin
		key advantag	EHC <sup>®</sup> Reagent for Tree As featured in Remediati	Enhancing Reductive Dechlorination		Technology Overview     White Paper
	<u> </u>	Heavy Met Dr. Alan Seed	concentration area from ranged as high as 592,0	Enhancing Reductive Dechlorination article by Pollution Engineering		
		specific form	EHC*ISCR Respect Chi	Assessment Report of Sustainability of Green Remediation Technologies Using US EPA criteria, Maul Foster & Alongi, Inc. reviewed four potential green remediation tech emotified of leaftrist residue heating. and remme R transit for an arther of	mologies (EHC® Reagent,	FILTER
	<u> </u>	Bench Test Brianna Desja Solutions Lab	EHC <sup>®</sup> Reagent for Tree As featured in Remediati remediate TCE in grouns	Klozur= Persulfate: The Impact of Sulfate Residual		
	G	Design Cor	EHC* ISCR Rangent Chi	Kiczur# activated persultate is a strong oxidant that can oxidize and destroy many organic conta product sultate in the process. This discussion explores the impact of sultat	minants, generating the by-	
	4	Dan Leigh, P. The discussio	Treatment for Soil Cor EHC= Reagent was evals pesticides (OCPs). The is	Emerging Contaminant Spotlight: 1,4-Dioxane A discussion focusing on the emerging contaminant 1,4-dioxane, its impact on the environment Klozuriti activated persultate provides an effective means of treating 1,4-dioxane co	and regulatory drivers.	
			EHC* ISCR Reugent Chi	Guidelines for Klozur® Persulfate Alkaline Activation An overview of the guidelines and use of common alkaline sources for the activation of Klozur SP	and Klozur KP	
				Sefe Use of Klozur Persulfate Activetors Activators are used with Klozur Persulfate to convert the penulfate anion, a strong but kinetically sulfate radical, a much stronger and kinetically faster oxidative species ca	y slow oxidant, into the	



## **Our Approach**

#### Site Evaluation

SITE EVALUATION FORM		
CONTACT INFORMATION		
COMPANY	CONTACT NAME	
ADDRESS.	PHONE NUMBER	
CTT:	PROVINCE DIAL	
POSTNL CODECOUN	nex	
STE DETAILS		
SITE NAME	LOCATION	
PROJECT STATUS: PEASEBUTY STUDY	WORKPLAN DEVELOPMENT PENDING FIEL	DIMPLEMENTATION OTHER
STE GLANAP OBJECTIVES AND TIMING:		
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#### Customer Provided Site Information:

- Contaminant Information
- Geochemical Data
- Hydrogeology/Geology Information

#### www.peroxychem.com/remediation

#### **Cost Effective Solutions for Your Site**



#### Initial Product Demand Estimate:

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



## **Evonik Soil & Groundwater Remediation**

Field-Proven Portfolio of Remediation Technologies

#### **Chemical Oxidation**

- Klozur<sup>®</sup> Persulfate Portfolio
  - Klozur® SP
  - Klozur® KP
  - Klozur® One
  - Klozur<sup>®</sup> CR
- Hydrogen Peroxide

#### Aerobic Bioremediation

- Terramend® Reagent
- PermeOx® Ultra
- PermeOx<sup>®</sup> Ultra Granular

#### Metals Remediation

• MetaFix® Reagents

#### <u>Chemical Reduction</u> • EHC ISCR Portfolio

- EHC<sup>®</sup> Reagent
- EHC<sup>®</sup> Liquid
- EHC <sup>®</sup> Plus
- Daramend<sup>®</sup> Reagent

Enhanced Reductive Dechlorination

- ELS<sup>®</sup> Microemulsion
- ELS<sup>®</sup> Liquid Concentrate
- ELS<sup>®</sup> Dry Concentrate

#### **BioGeoChemical**

• GeoForm<sup>™</sup> Reagents





## **Contaminants Treated**





# **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<sub>2</sub>)
- 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



Groundwater Flow  $\rightarrow$ 



## **Overview of Reductive Mechanisms**

#### **Direct Chemical Reduction**

A **redox** reaction occurs when there is direct contact with ZVI and halogenated contaminants **Red**uction: ZVI can offer up 2 electrons for dechlorination or reduction of the halogenated contaminants **Ox**idation: 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





## **Overview of Reductive Mechanisms and Pathways**

## **Indirect Chemical Reduction**

Occurs when soluble ferrous iron precipitates out of solution as reduced iron minerals

- Iron Sulfides: pyrite, mackinawite, greigite
- Iron Oxides: magnetite, iron hydroxide / green rust

These iron minerals support abiotic dechlorination

Since soluble ferrous iron can migrate, indirect chemical reduction can occur beyond the placement zone



Main Abiotic Pathway (β-Elimination)





## **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<sup>®</sup> Microemulsion or Concentrate
  - 2. EHC<sup>®</sup> 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



#### 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 m<sup>2</sup>
- Treatment area thickness: 9 m
- GW table: 8 m bgl
- Saturated soil matrix: gravelly sand
- Seepage velocity ≈ 280 m/yr
- GW natural geochemical conditions: Aerobic, neutral pH
- COCs: CT > 5 mg/l, CF > 3 mg/l, TCE > 0.5 mg/l, CrVl > 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).



## **Remodeling Flow Rates of Wells near Treatment Area...**

#### Goals:

- 1. Reduce flow rates below threshold values, to protect effectiveness of the ERD treatment
- 2. Protect effectiveness of the Pump & Treat system already in place in the treatment area
- 3. Use the active wells as a downstream emergency defence against the ERD treatment

Through use of the mathematical model, optimal flow rates were defined for each well:



To keep seepage velocity < 300 m/year in the ERD treatment area **(Goal 1)** 



P&T groundwater in a wide downstream area (Goal 2)
Effectively capture flow from the injections area (Goal 3)





## **ISCR / ERD Field Activity**





- Application: Direct injection through 28 fixed Manchette tubes
- Injection campaign ≈ 306 kg of ELS® Concentrate per point, plus 70 kg of organo-iron powder
- Total injection volume: 96 m<sup>3</sup> of EHC® Liquid emulsion, in 10% solution
- Average injection pressure: ≈ 17 Bar
- Average injection flow rate: ≈ 17 L/minute
- Field activities start date: December 2017
- Plume Hydraulic control: Pump & Treat







## **Post-Application Results (18 months) in µMol/L**





## Post-application results (15 months) in µg/L





## Post-application results (12 months) in µg/L





## Post-application results (12 months) in µg/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!





