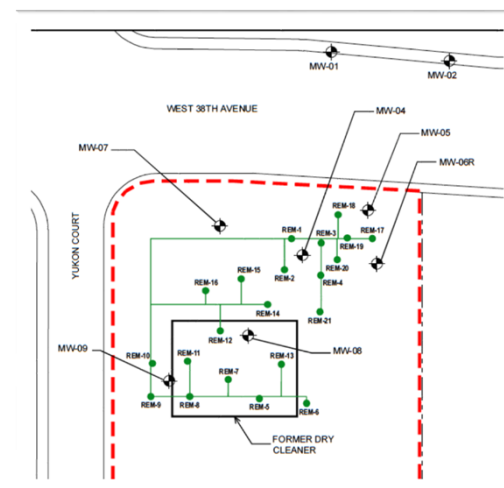
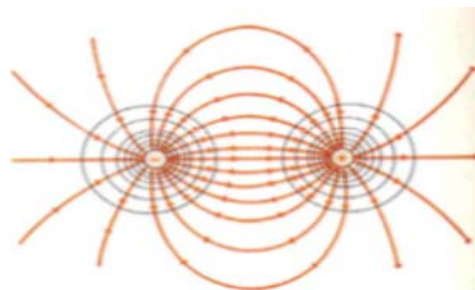


# Case Study: Utilizing a Low-intensity Electrochemical Technology for Treating Chlorinated Compounds in Tight Subsurface Matrix



**Song Jin, PhD, CHMM**

**Advanced Environmental Technologies LLC**



# About Us

- Advanced Environmental Technologies (Fort Collins, CO)



- Co-Author: Paul Fallgren (AET)

# Outline

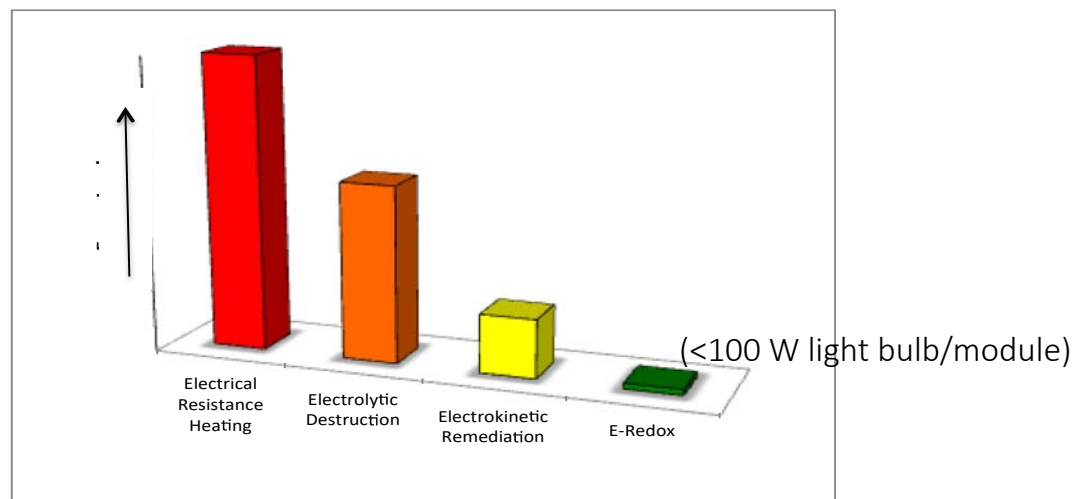
- Low-intensity Electrochemical Reduction and Oxidation
- Technology description
- Case study in Charleston SC
- Summary

# Electro-Chemical-Redox Reactions (E-Redox<sup>®</sup>)

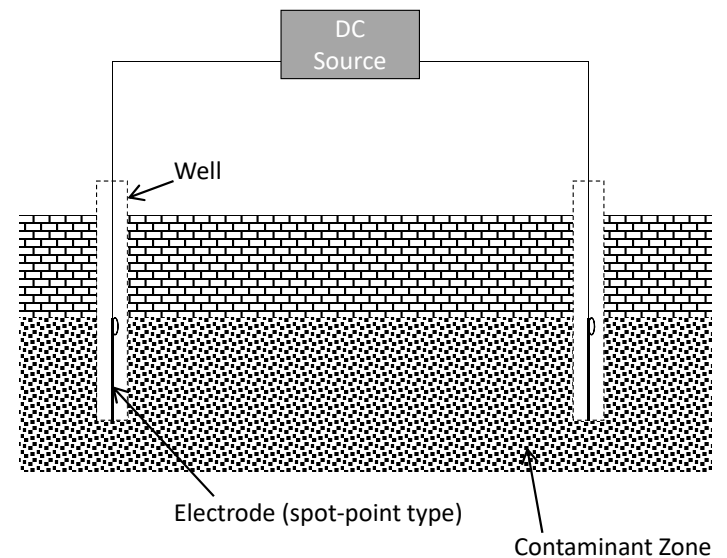
- Reactions via electron transport and shifts of particle surface charges
  - Reduction
  - Desorption
  - Rapid drop of redox potential
  
- Friendly for fine-grained lithology: silts & clays

# E-Redox<sup>®</sup>

- Establishes a low-voltage/low-amperage static electric field in the contaminated matrix.
- Promotes reductive destruction and desorption of source compounds from soil into water



Relative Electrical Energy Requirement



Patented by AET, 1<sup>st</sup> Field Application 2014  
Jin et al., 2008. Chem Eng J, 140:642  
Jin and Fallgren 2009, J Haz Mat, 153:127  
Luo et al., 2010. Chem Eng J, 160:185

# “Micro-conductor” Mechanism

Soil particles in the influenced matrix act as micro-conductors, become polarized, and act as micro-capacitors

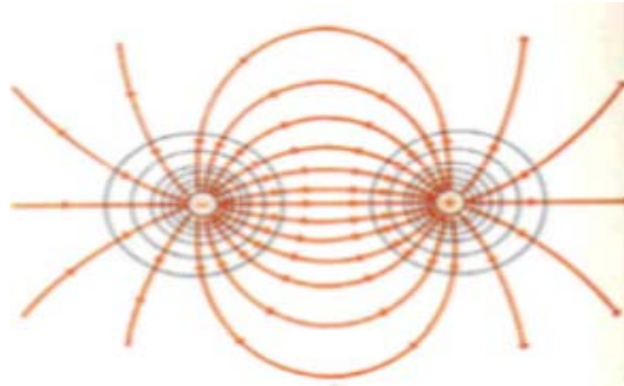
- Reductive destruction of chlorinated solvents

Constant shifts of surface charges on soil particles disturb the “water cage” configuration and weaken the constituent's adsorption

- Desorption of contaminants from soil into water
- Elimination of “rebounds”

\* Dietmar Rahner, Dresden U of Technology, 2002

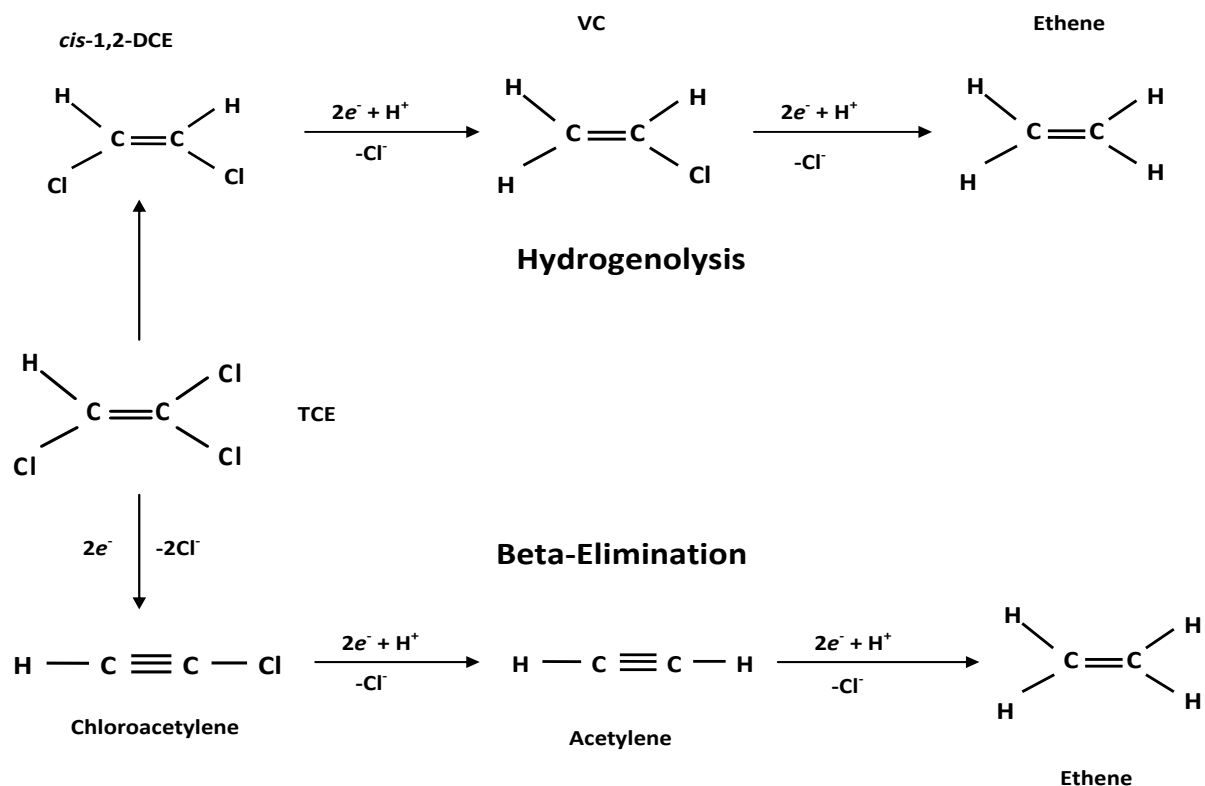
# Static Electric Field



Field data indicate a radius of influence (ROI) of ~25 ft in clay and silts; >50 ft for matrices with injection history of carbon, ZVI, or other conductive compounds

Electrodes spacing: ~25 ft for mixed saturated and unsaturated matrices

## Reductive Pathways of Chlorinated Ethenes

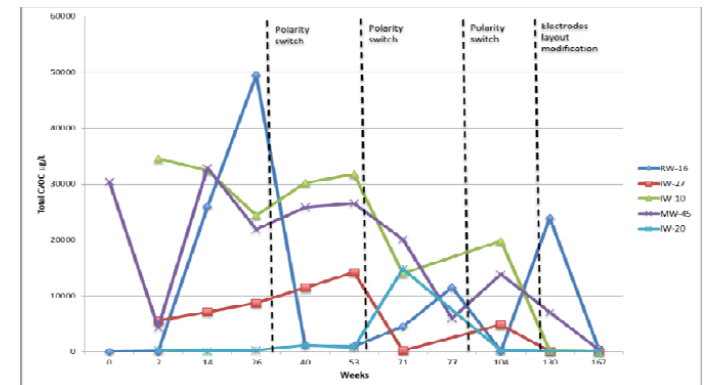


\*E-Redox® (I) primarily drives abiotic dechlorination (beta-elimination). Additionally, the process enhances opportunistic microbes to carry out biological reductive dichlorination as well as benefits mass desorption

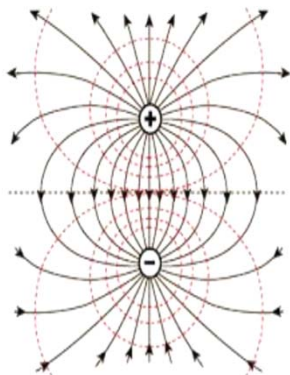
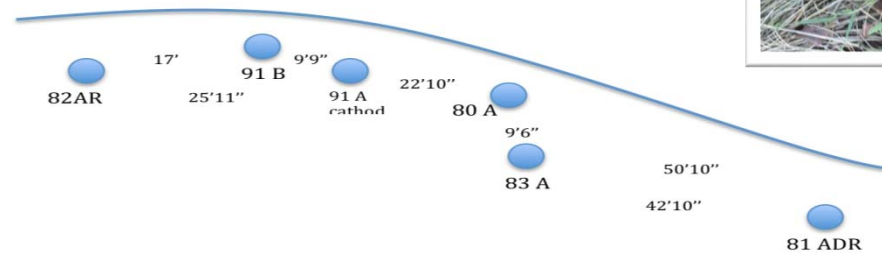


# Contaminants Mass Mobilization

- Initiates back-diffusion of COCs
  - Localized redox reactions at the soil/sediment particle surface cause desorption of contaminants
- Enhances mass removal by pump-and-treat, soil vapor extraction (SVE), dual phase extraction (DPE)/multiphase extraction (MPE) etc.



# E-Redox<sup>®</sup> Rapid drop of redox potential



- ORP decreased >115 mV after 30 min and continued to decrease in the area with continued E-Redox-I operating
- During the testing period of 4 hr, E-Redox-I system has a measureable ROI of >26 feet from either electrode outward

\*Fallgren, P.H., Eisenbeis, J.J., Jin, S. 2018. *J. Environ. Sci. Health Part A* 53:517-523.



## Example Field Applications of E-Redox® (I)

Site	Location	Contaminant	Matrix	Scale
Instrument Factory	Taiwan	Chlorinated Ethenes	groundwater	Pilot
Superfund Site	Utah	Chlorinated Ethenes	Groundwater	Pilot
*Former Explosives Testing Field	California	Perchlorate, VOCs	Groundwater	Pilot
<b>Former Adhesives Plant</b>	<b>South Carolina</b>	<b>Chlorinated Ethenes</b>	<b>Saturated soil and groundwater</b>	<b>Full scale</b>
Former Industrial Facility	United Kingdom	Chlorinated Ethenes	Saturated soil and groundwater	Full scale
*AK DOT Facility	Alaska	Chlorinated Ethenes	Saturated soil and groundwater	Full scale
Brownfield Sites (former dry cleaner)	Colorado	PCE, TCE and other chlorinated ethenes	Saturated soil and groundwater	Full scale
Former CrVI manufacture)	China	Hexavalent Cr	Saturated soil and groundwater	Demonstration

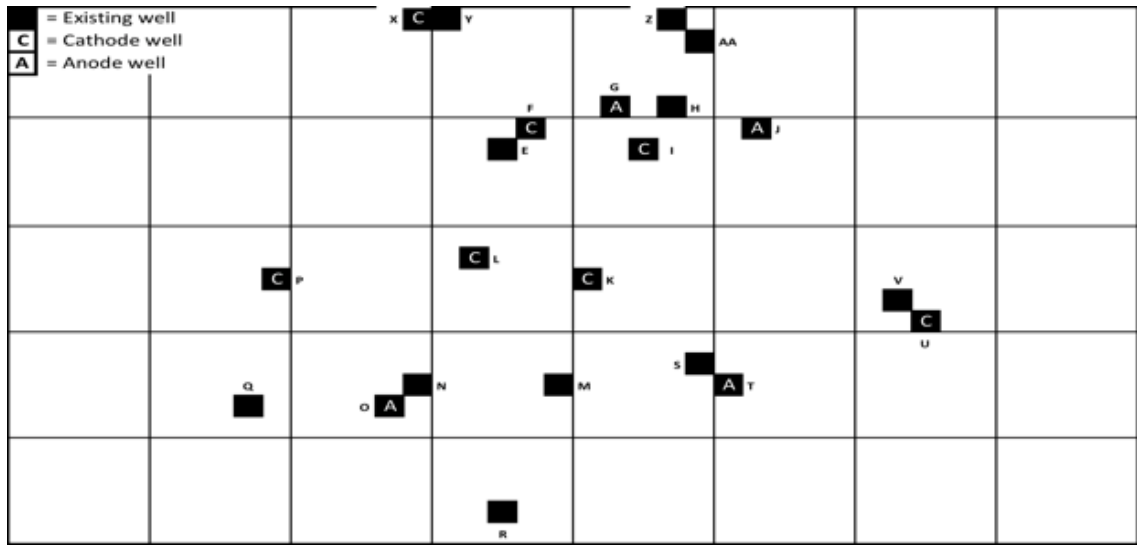
# Case Study (Charleston, SC)



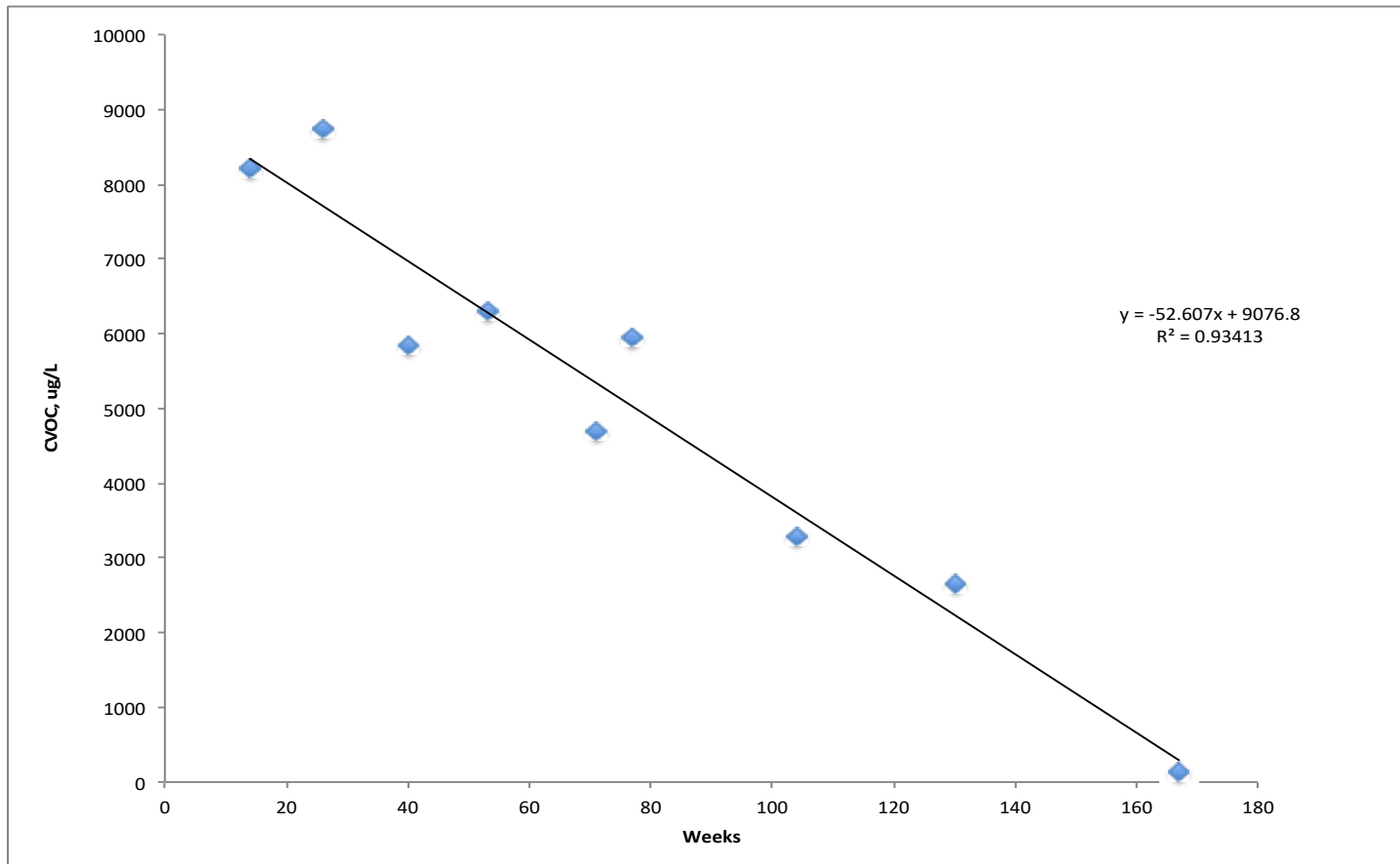
**SAME**

 **DCHWS**  
Design and Construction Issues at Hazardous Waste Sites

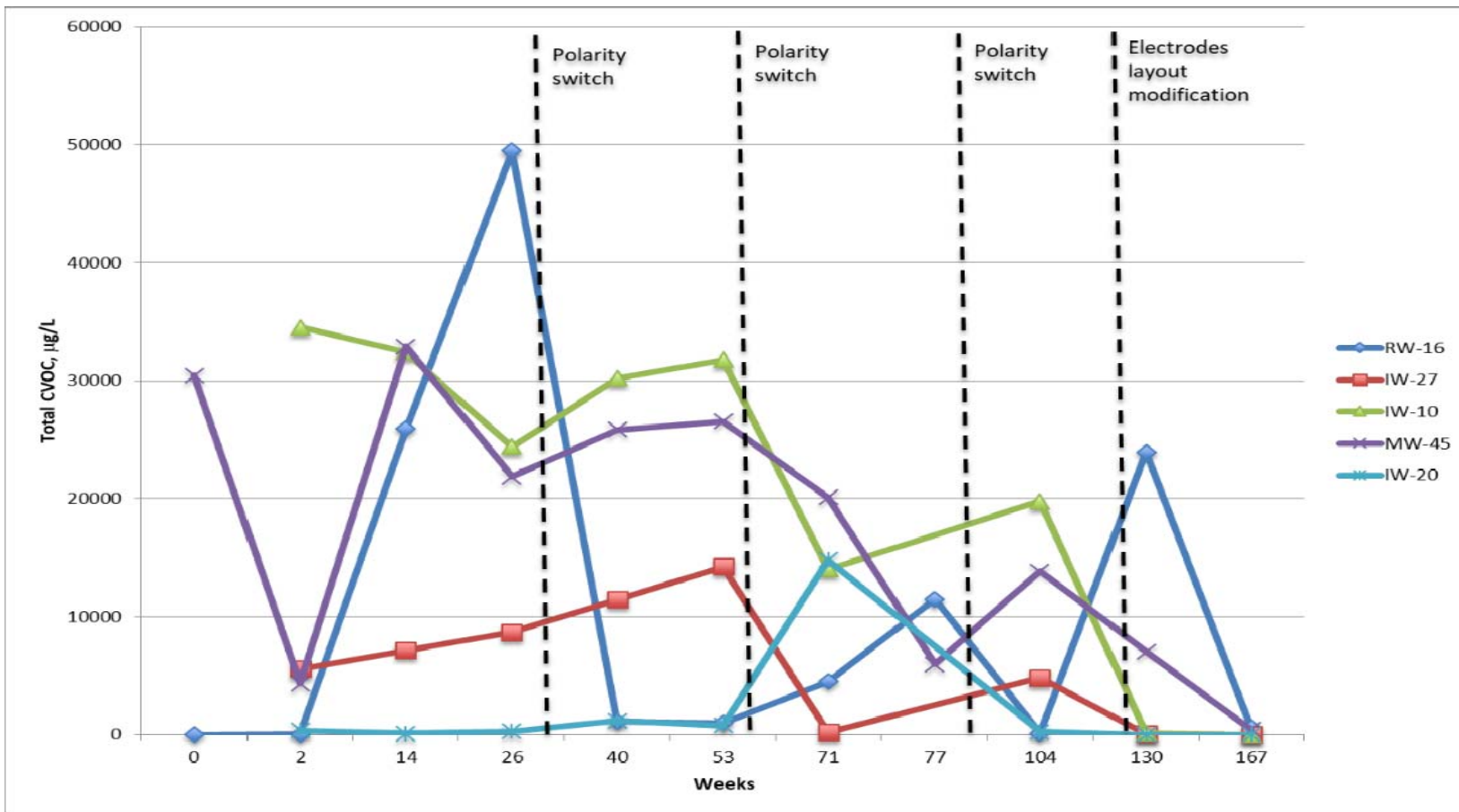
March 29, 31 and April 1, 2021





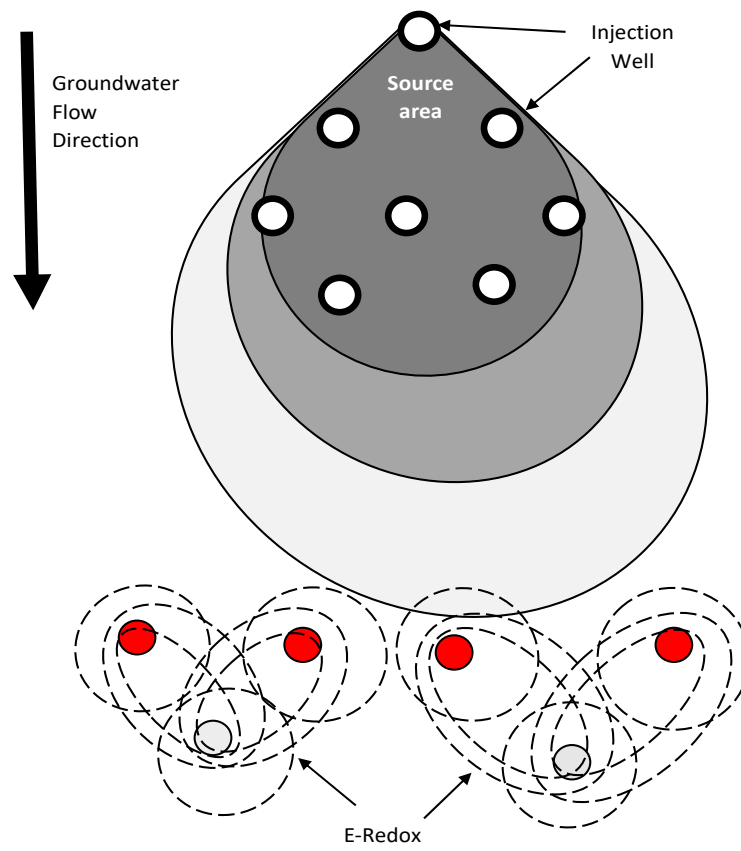


Total site-wide chlorinated volatile organic compounds (CVOC) concentrations



E-Redox enhanced desorption that contributed to the mass removal





Proposed Combined  
remediation with  
oxidants/reductants injection  
and an E-Redox barrier

## E-Redox<sup>®</sup> (I) Challenges (Electrical Conductivity)

1. Significant amount of underground conductive structures such as metal piping in the target matrix – avoid
2. Vadose zone with substantial low conductivity – rearrange electrodes layout
3. Lack of electricity source – alternative power sources



## E-Redox<sup>®</sup> (I) - SUMMARY

1. Initiates and sustains both abiotic and biological reductive (dechlorination and even defluorination) reactions
2. Not limited by matrix physical permeability, works for clay
3. Desorption of COCs (CVOC and PFAS) into the aqueous phase for enhanced mass removal
4. Instantaneous drop of redox potential in the matrix, favoring reductive reactions
5. ROI of 25-50 ft; consumes minimum energy, convenient O&M, fits remote sites
6. Synergistic to other remediation technologies:
  - Rejuvenate ZVI
  - Extends electron donor longevity
  - Rapidly establishes low redox condition for reductive degradation



E-Redox<sup>®</sup>



Song Jin Ph.D., CHMM

E: [sjin@aetecs.com](mailto:sjin@aetecs.com)

T: 970.889.8410

THANK YOU!

**SAME**



**DCHWS**

Design and Construction Issues at Hazardous Waste Sites

March 29, 31 and April 1, 2021

# E-Redox<sup>®</sup> Enhanced Contaminant Desorption

- Hydrophobic compounds are surrounded by water molecules forming a “cage” around compound
  - The water at the surface of mineral particle is more ordered than around the hydrophobic compound
  - This difference in order between sides of the compound causes the compound to adsorb onto mineral surface
- When under electric field
  - The interface conditions change causes the compound to desorb
  - Increased order of water on the side of the compound that was originally less ordered, causing it to desorb from the compound surface
- Soil organic matter (SOM) has regions that are polar and non-polar
  - The non-polar regions will adsorb the compound more strongly than observed on mineral surface (why greater SOM will adsorb more hydrophobic compounds)
  - When under the electric field, non-polar regions polarize and weaken the bonds between the hydrophobic compound