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A decade of large-scale enhanced reductive dechlorination

The evolution in the usage of a high-volume controlled-release electron donor substrate

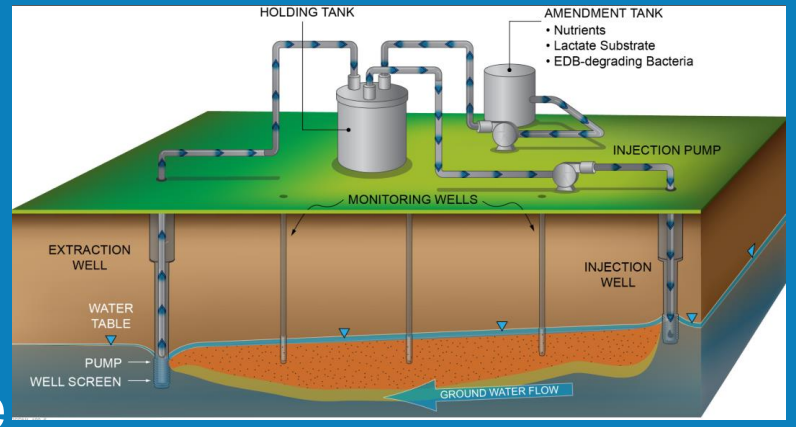
Gareth Leonard

Groundwater Quality 2019

Introduction

- Enhanced Reductive Dechlorination used for remediation of CHC's for over 2 decades
- Started with the use of soluble substrates
- Late 1990's controlled/slow release substrates came on the market
  - Overcome vinyl chloride stall
  - Avoid multiple applications
  - Low volume

    = good for low permeability
- But chlorinated solvent plumes can be BIG!
- Wanted to create a version for large plumes



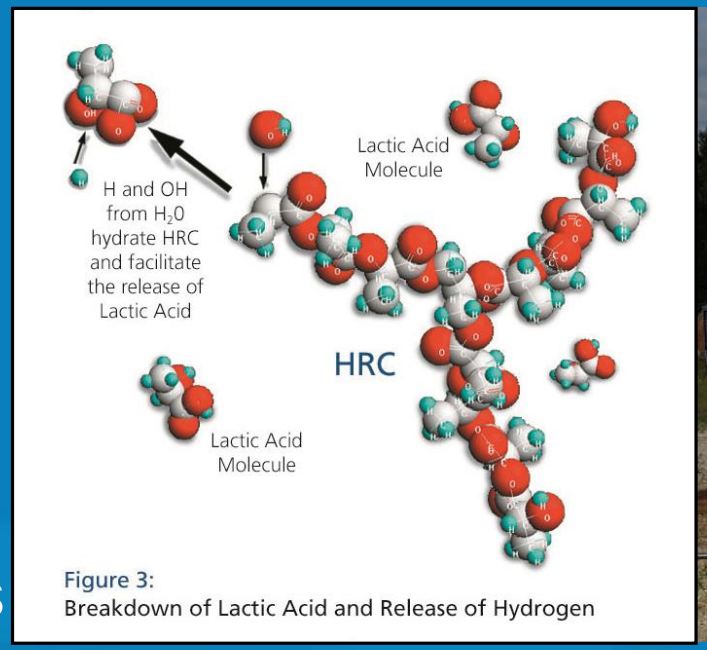
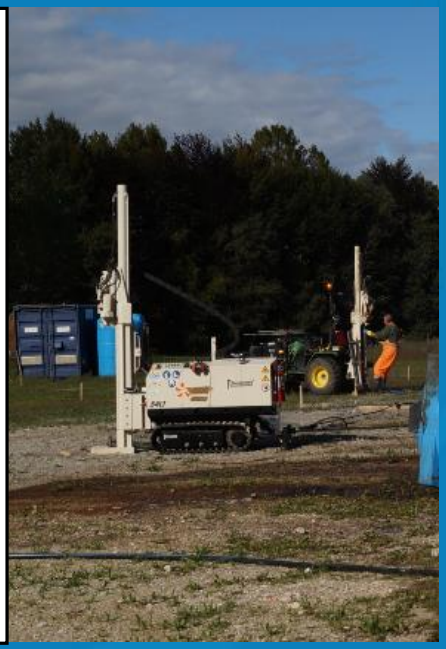


Figure 3:
Breakdown of Lactic Acid and Release of Hydrogen



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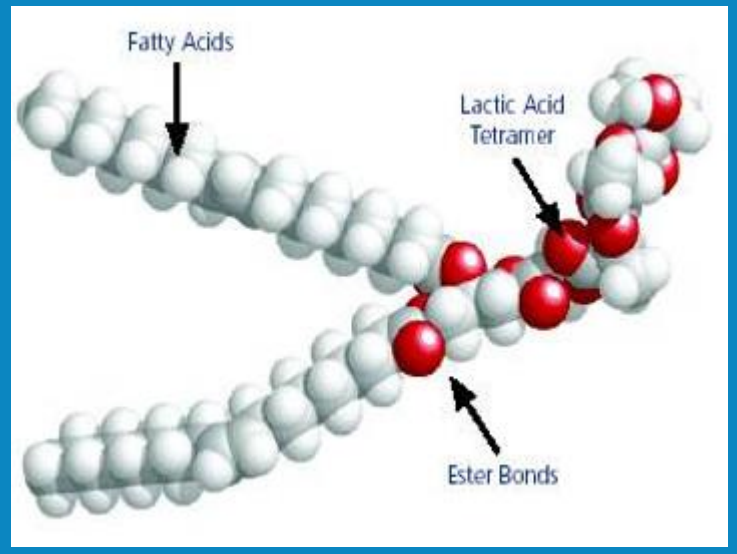
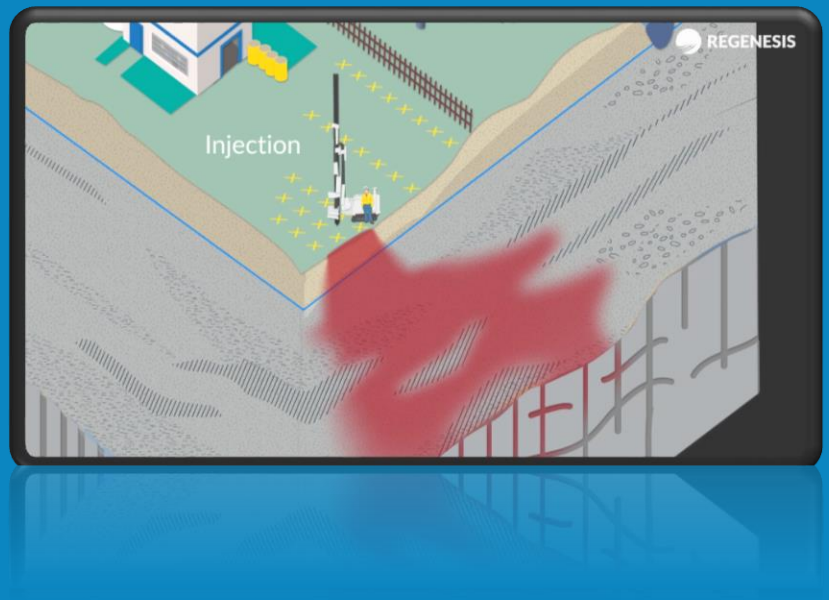
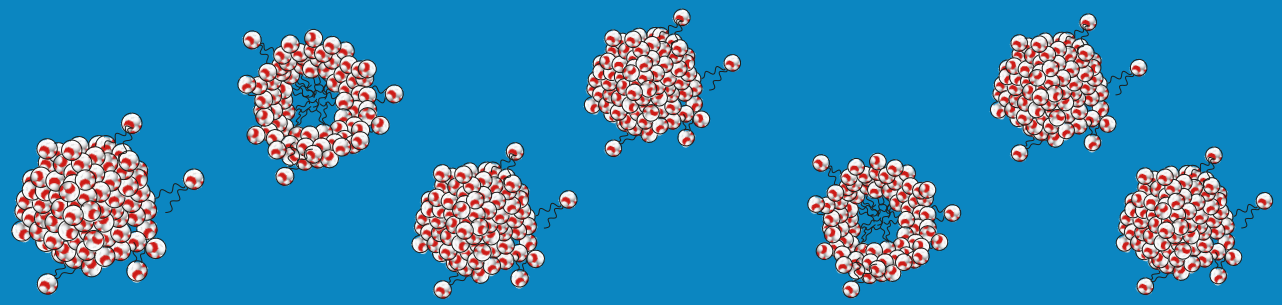
Large Scale Enhanced Reductive Dechlorination







Micelle Formation

Self-distribution

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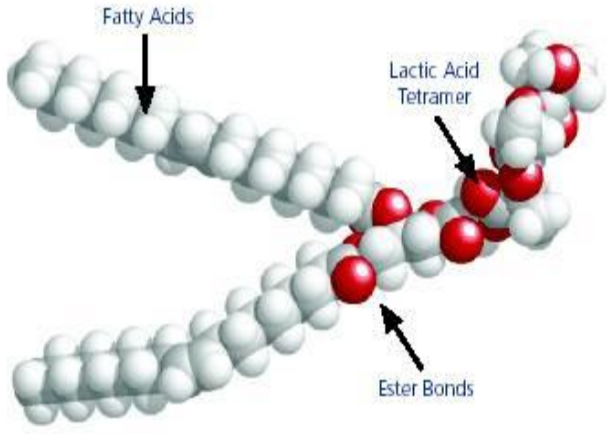
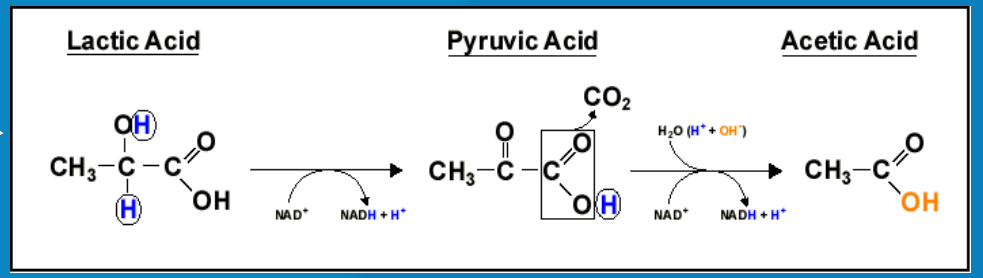
Enhanced Reductive Dechlorination

Controlled-release electron donor

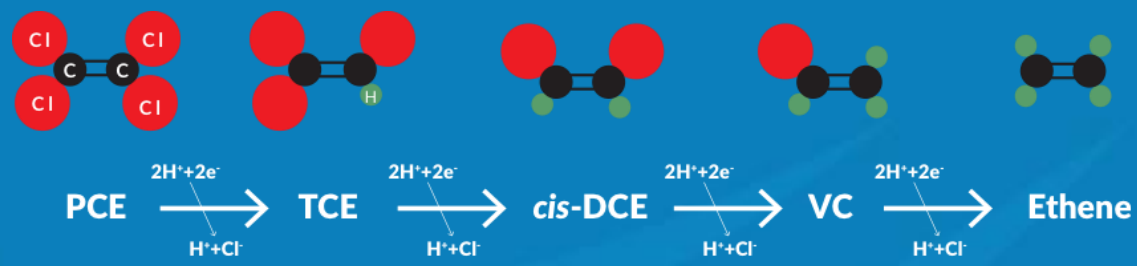


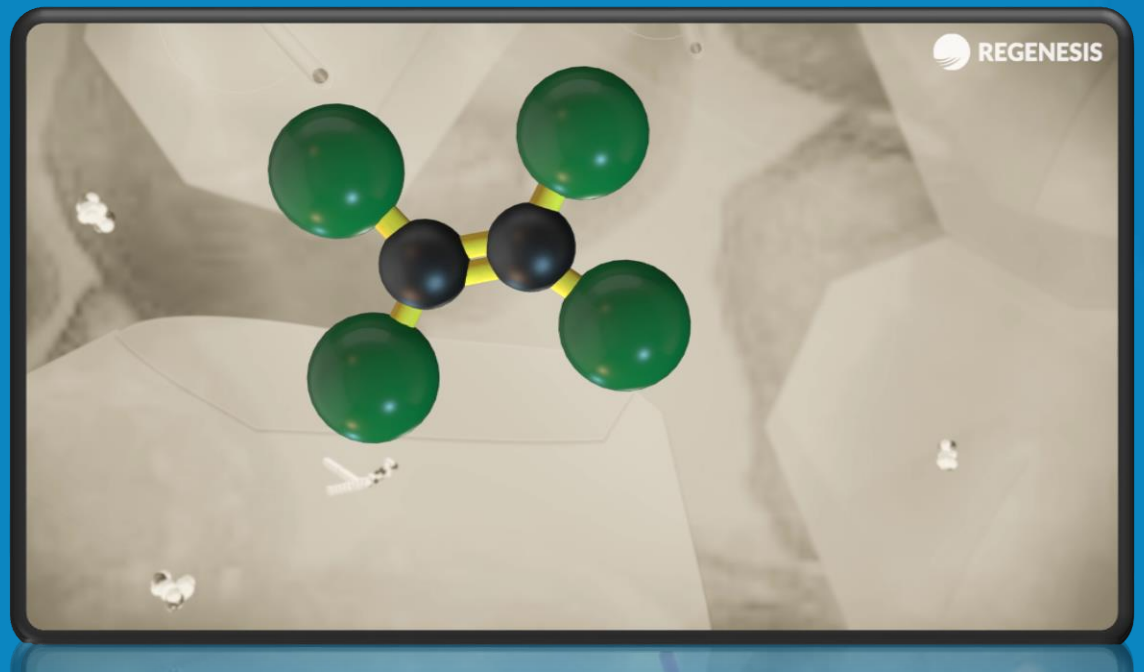
Dissolution

Fermentation



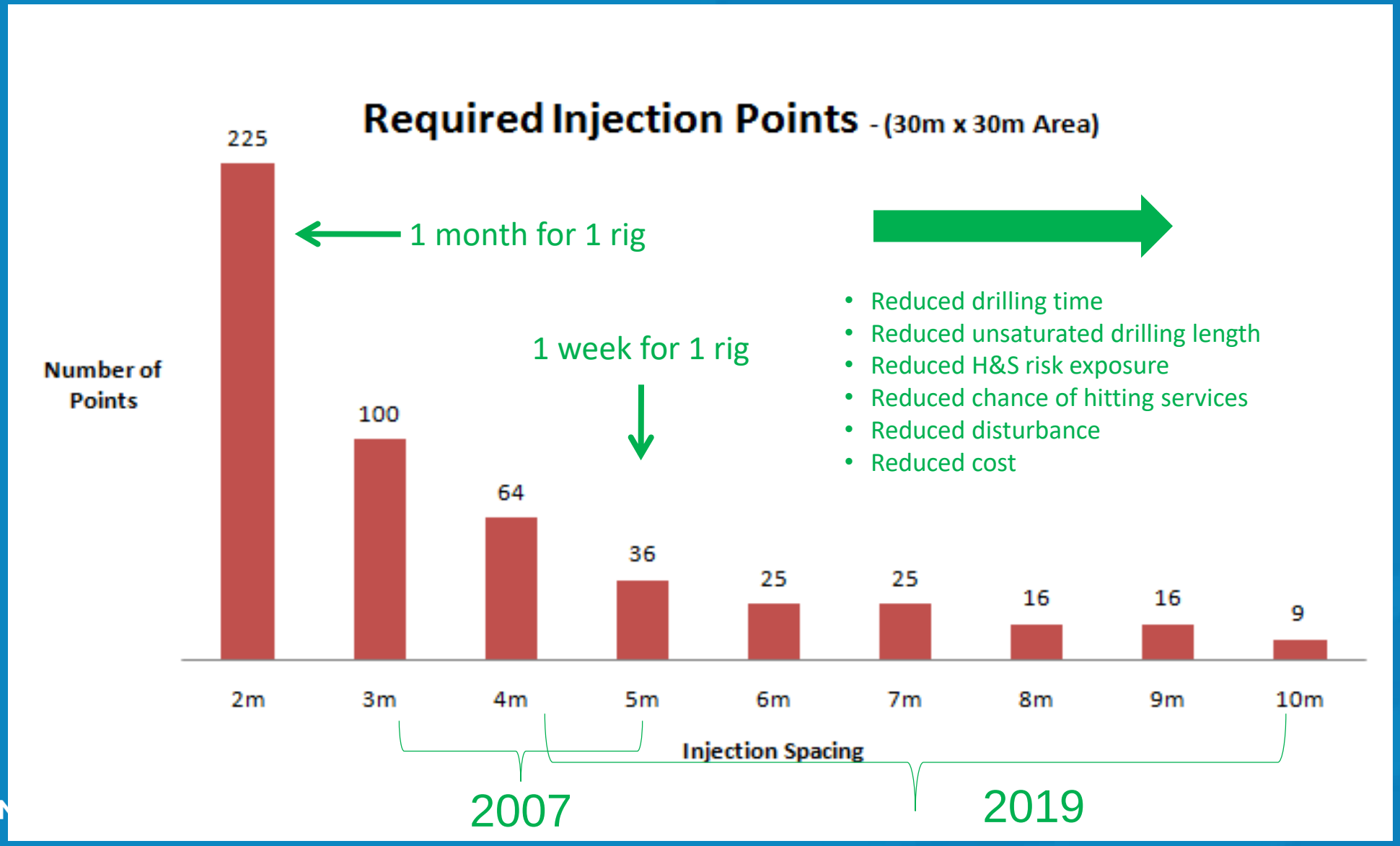
Hydrogenolysis





Lessons Learned: Application Development

- The importance of spacing



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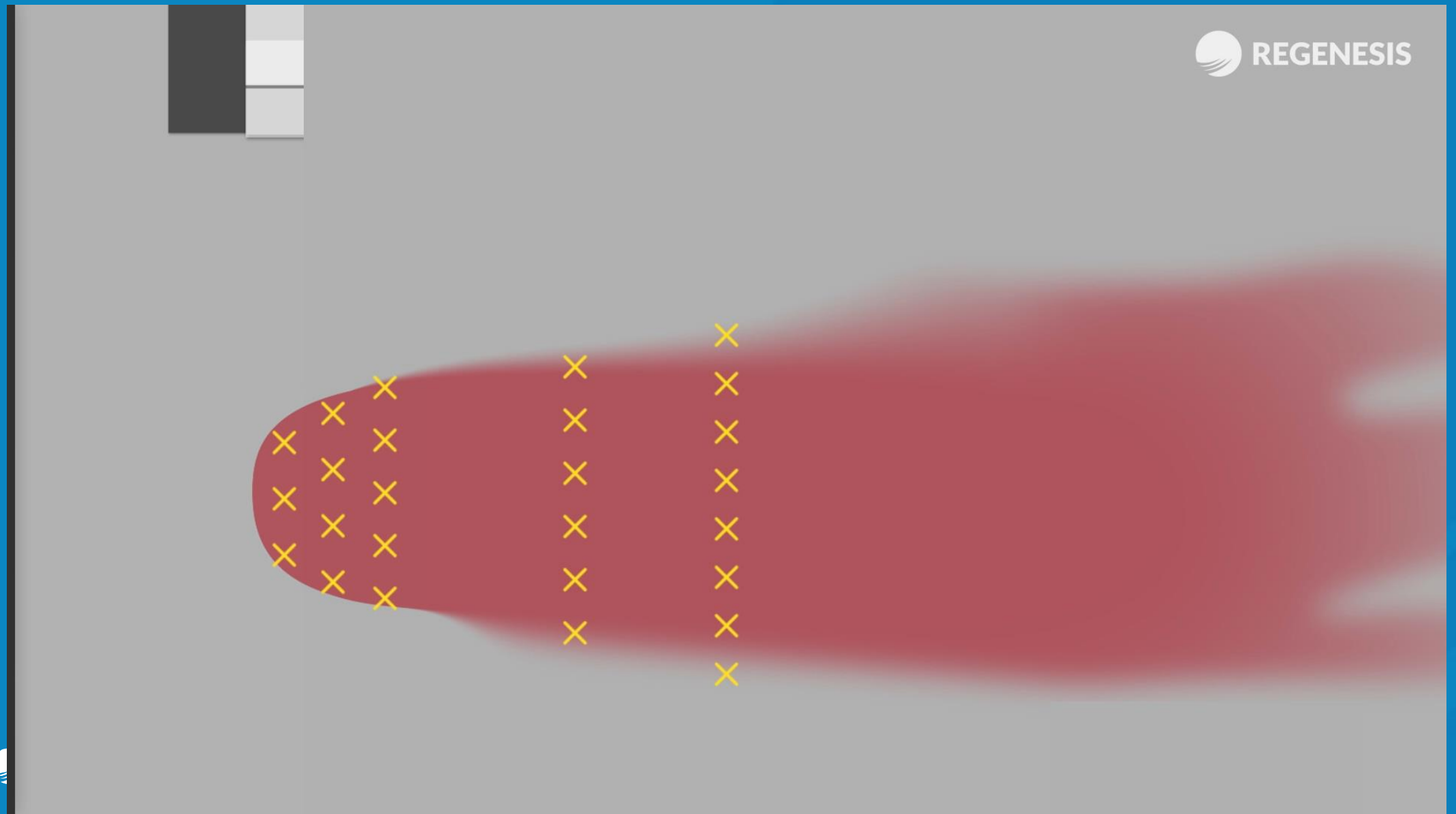
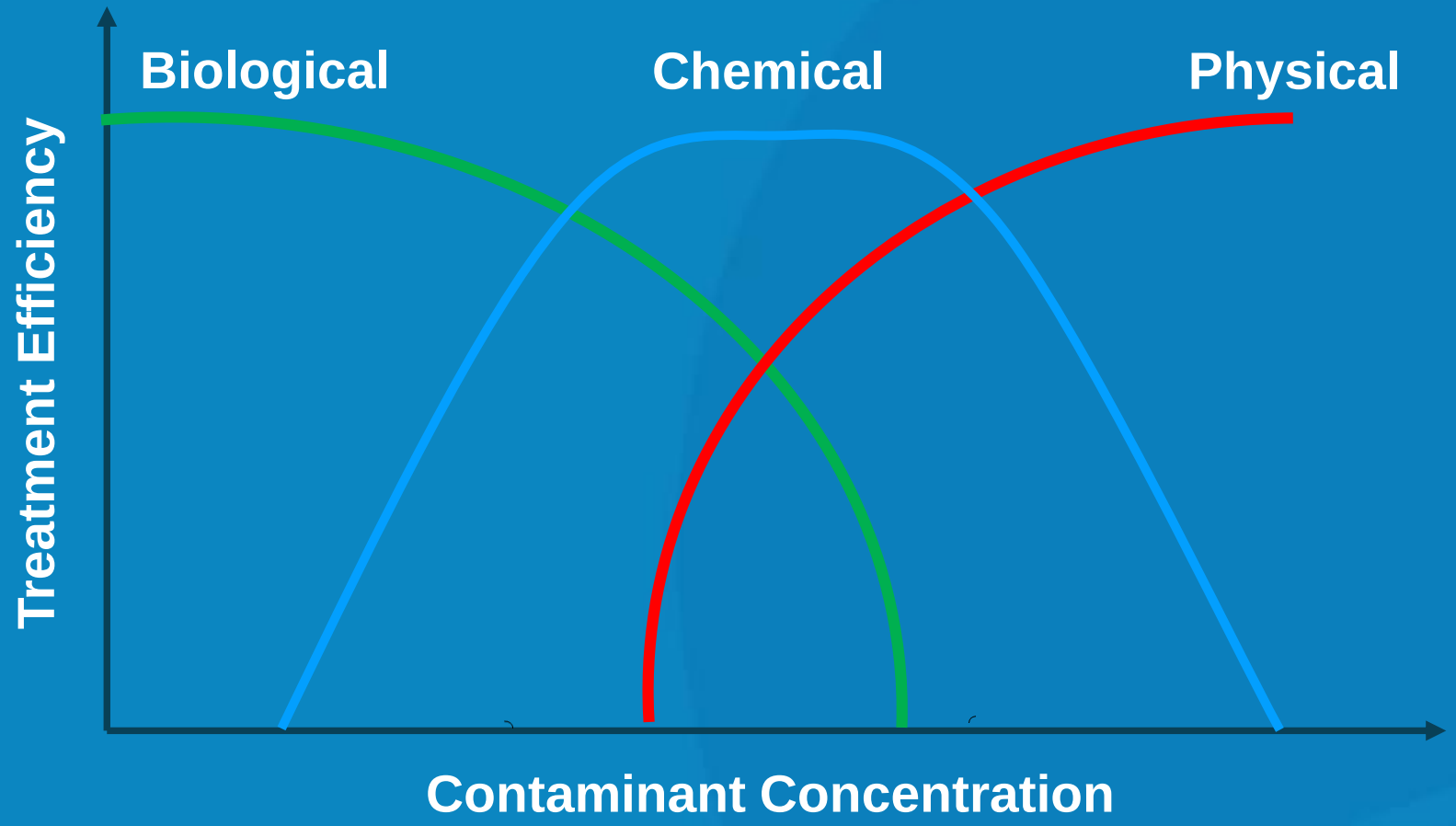


Lessons Learned: Treatment Envelope



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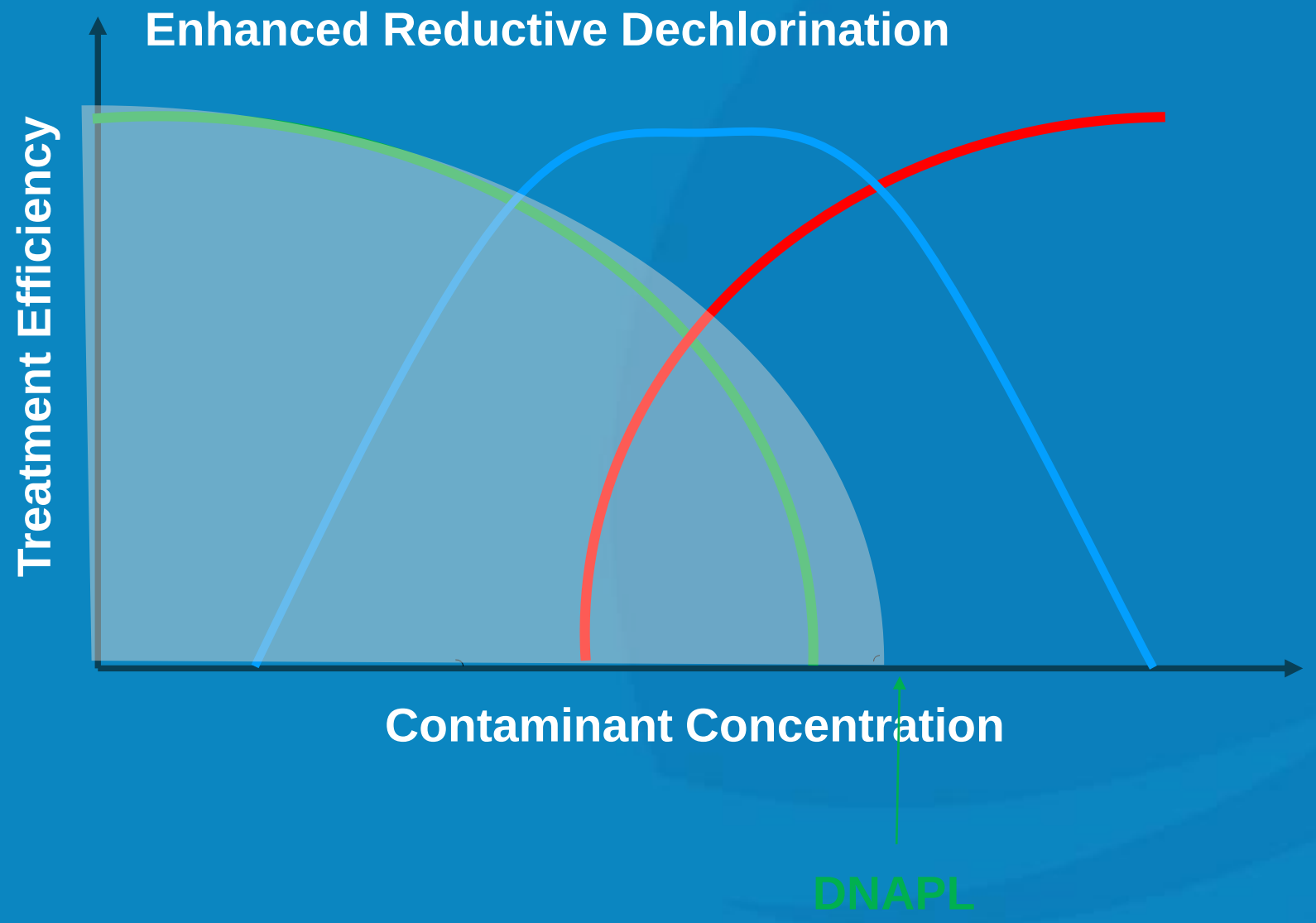
Lessons Learned: Treatment Envelope



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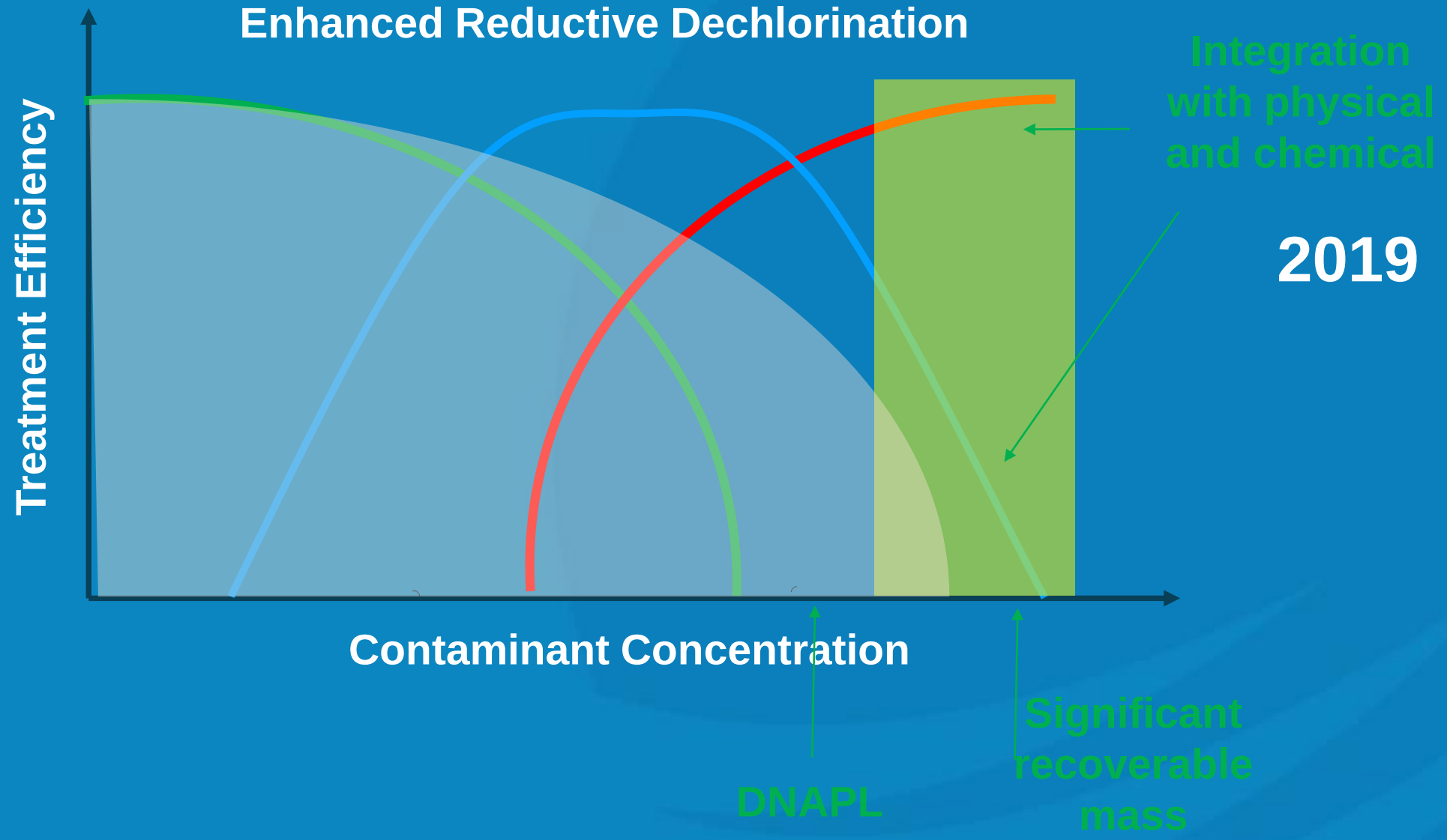
Lessons Learned: Treatment Envelope



Lessons Learned: Performance

Multi-site study:

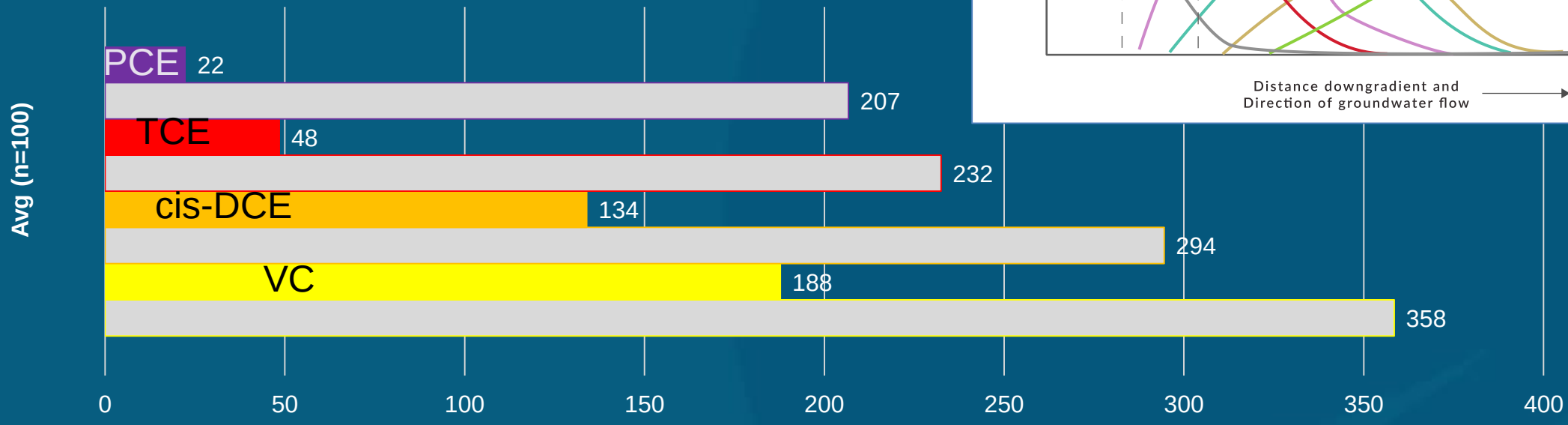
- 24 Sites within ERD Grid Array Treatments (100 wells)
- Industrial or Dry Cleaner Sites
- 4 Common Chlorinated Ethenes (PCE, TCE, cis-DCE, VC)
- 5 OOM CVOC range - 10s of ppb to 100s of ppm
- 69% Coarse-Grained
- 31% Fine-Grained

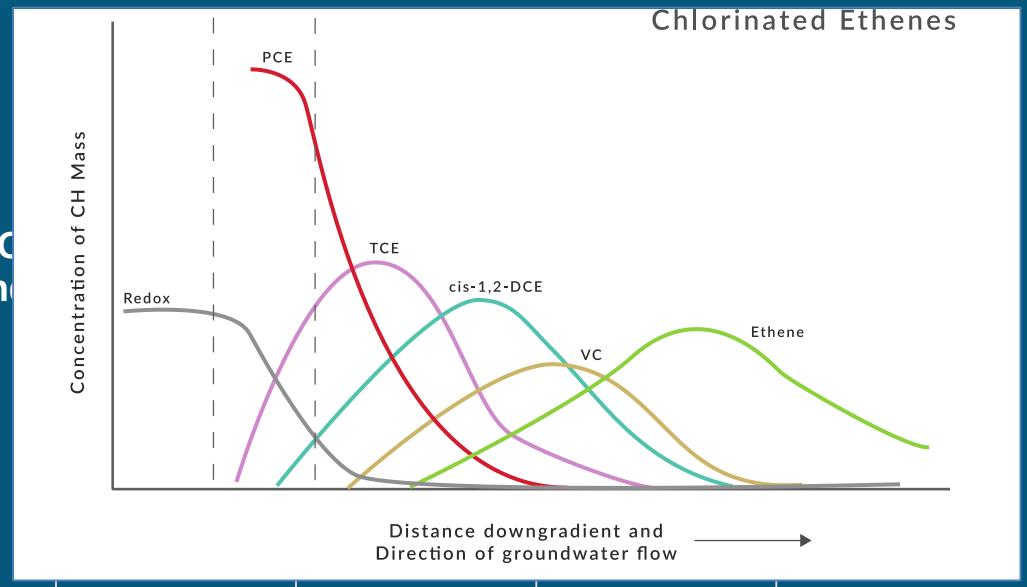
Starting Concentrations (µg / L)	PCE (n = 49)	TCE (n=83)	Cis-DCE (n=80)	VC (n=44)
Median - All Wells	323	103	120	4
Average - All Wells	6,364	7,340	4,610	915

- Donor, bioaugmentation and some with divalent iron reducing agent
- Average monitoring period =605 days

RESULTS – ALL WELLS

ERD Event Analysis - CVC
Average Days to Reach Peak Concentration an
All Wells





ERD EVENT TIMELINE - DAYS POST APPLICATION

- Max PCE Reached
- PCE - 90% reduced
- Max TCE Reached
- TCE - 90% reduced
- Max cisDCE Reached
- cDCE - 90% reduced
- Max VC reached
- VC - 90% reduced

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LESSONS LEARNED – ALL WELLS

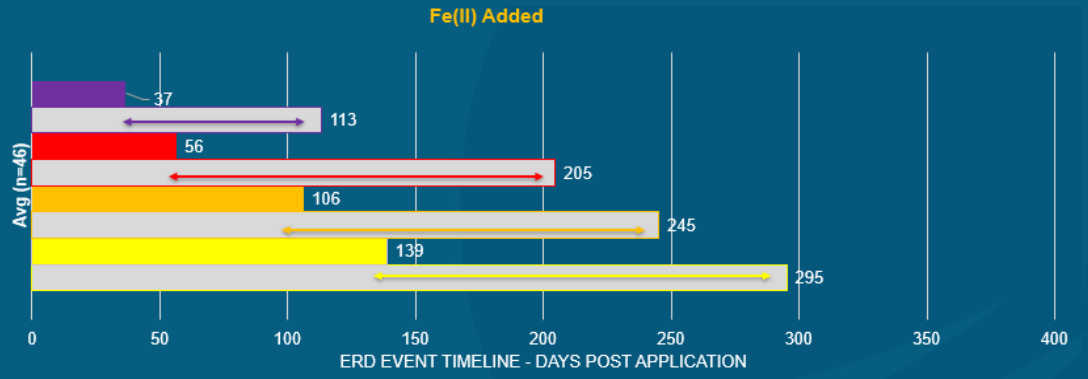
- Takes approx. 1 year to dechlorinate ‘big 4’ chlorinated ethenes (to 90% reduction from peak)
  - 358 Days (Avg); 305 Days (Med)
- Similar Degradation rates for all contaminants:
  - Slight faster for daughter CVOC’s

CE	Peak		90% red		Difference
PCE:	207	-	22	=	185 days
TCE:	232	-	48	=	184
cis-DCE:	294	-	134	=	160
VC:	358	-	188	=	170

- Daughter products do not build excessively
  - VC peak 18% of parent compound
- DNAPL slows reductions
  - However, high starting concentrations may assist reaching low targets
  - Creation of large and effective dehalogenating biomass
- Geology appears to be no barrier to performance

Evaluation of the effects of ISCR additive

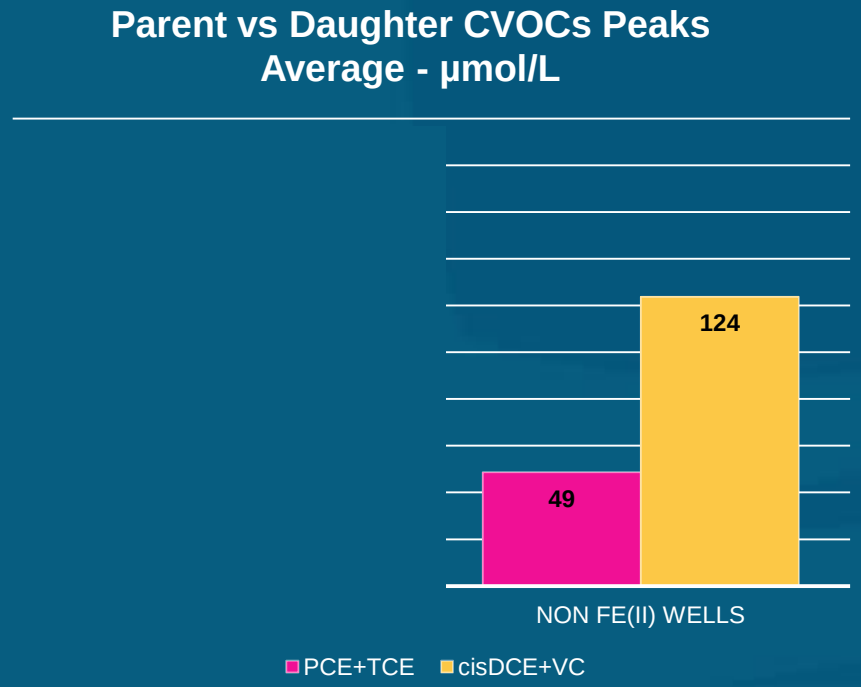
- Average difference in time from peak concentration to 90% reduction for each CVOC:



PCE -141 days
TCE -63 days
DCE -34 days
VC -11 days

More effective on more chlorinated compounds

- Effect on daughter product creation:



PCE+TCE→ cisDCE+VC conversion:

DVI Molar Ratios
~1:1 avg.

No DVI Ratios
~1:2.5 avg.

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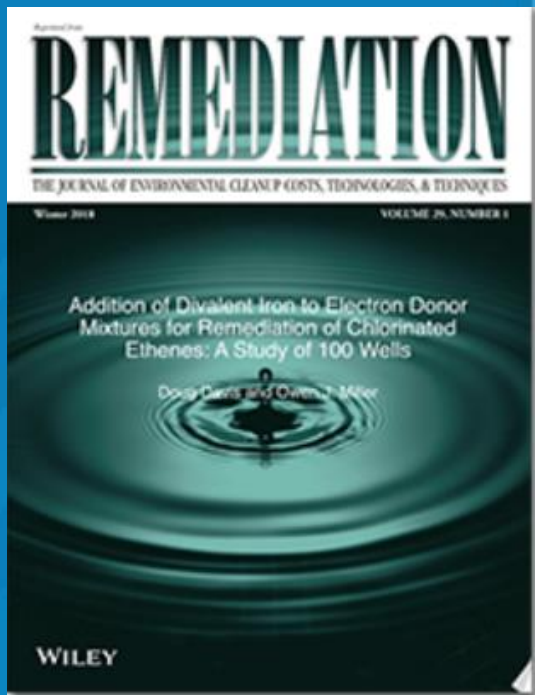
Conclusion

- ERD is a suitable technology for targeting large scale chlorinated solvent plumes
- Need to choose a substrate that minimises injection locations
- Full reductive dechlorination is to be expected with long term carbon release
- Daughter products break down readily
- ERD can target a wide range of contaminants from low concentration to DNAPL ‘ganglia’
- Combining with ISCR results in
  - Reduced project lengths
  - Reduced daughter product production
- ERD can be used in a wide range of geological settings



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Thank you

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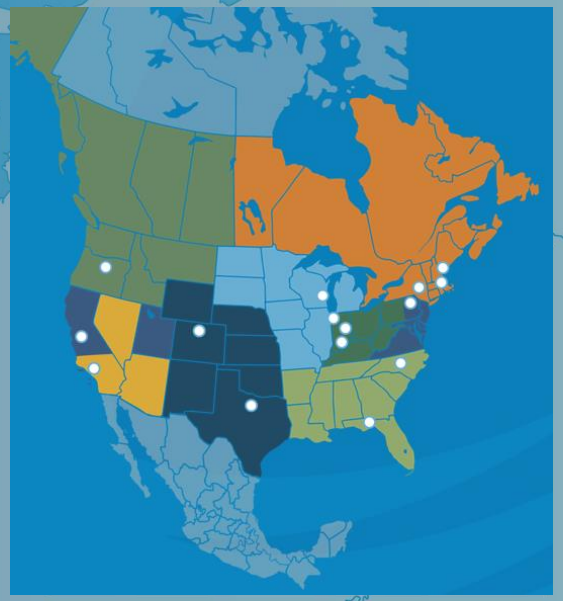

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