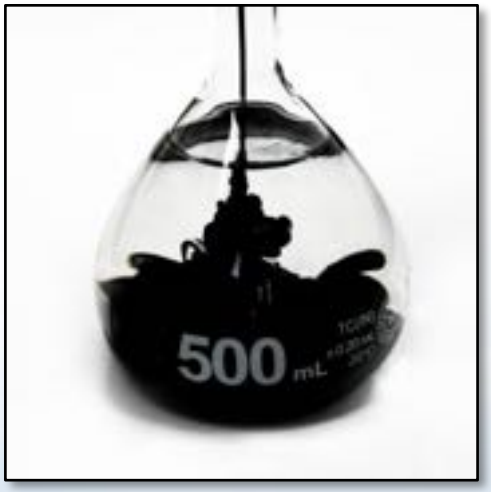
REGENESIS

PLUME STOP™

Liquid Activated Carbon

up-front orders of magnitude reduction and accelerated bio-destruction using a dispersive injectable reagent



Principal technology features

- **Rapid reduction of groundwater concentrations**
  - Multiple order of magnitude concentration reductions in days / weeks
- **Acceleration of contaminant biodegradation**
  - Elimination of low-concentration performance tailing
  - Ability to secure stringent clean-up targets
- **Wide subsurface dispersion**
  - Efficient fieldwork
  - Ability to address areas of restricted access, deep plumes etc.
- **Long-term efficacy**
  - The reagent is not consumed – it regenerates *in situ*

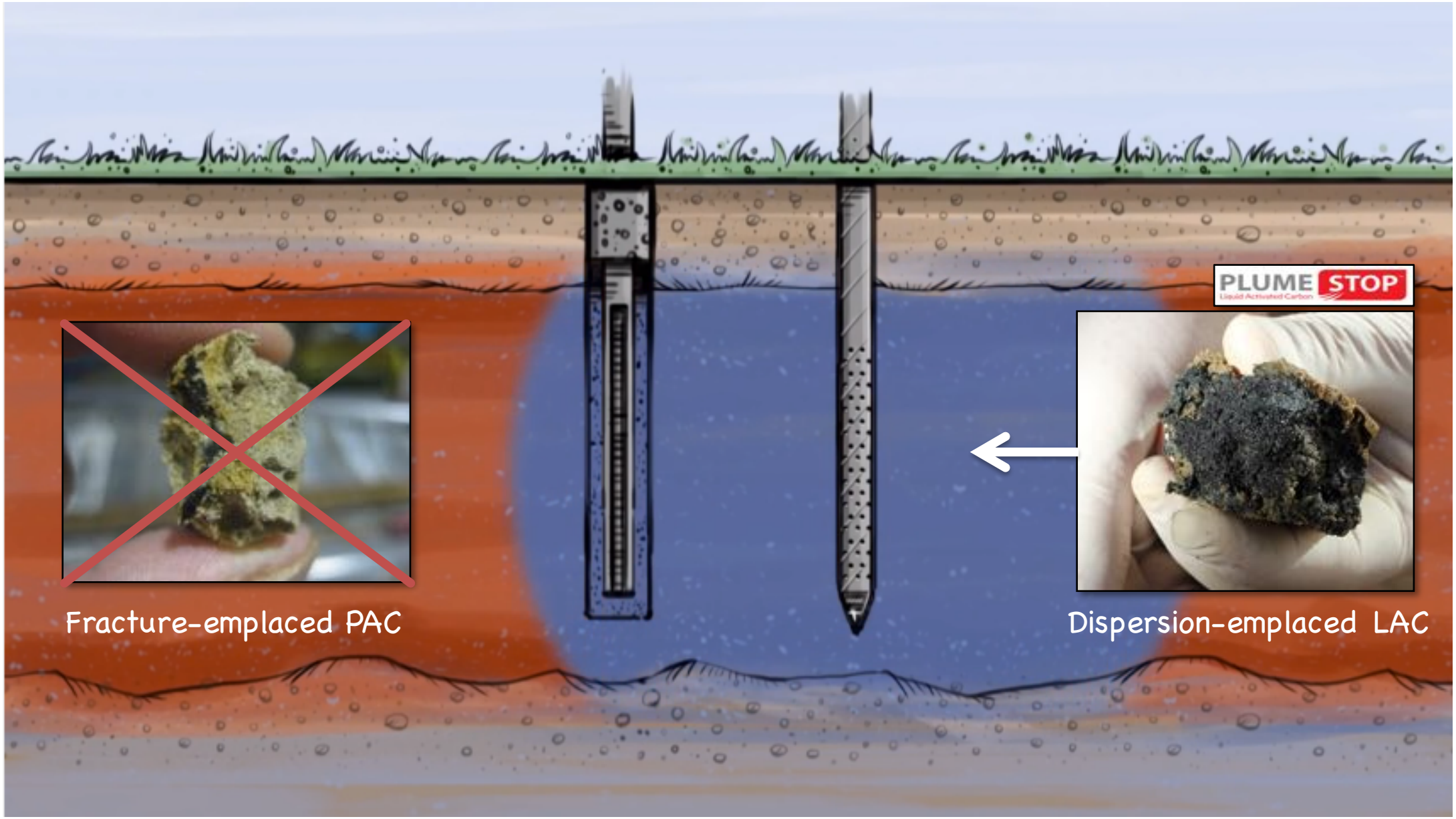
What it is

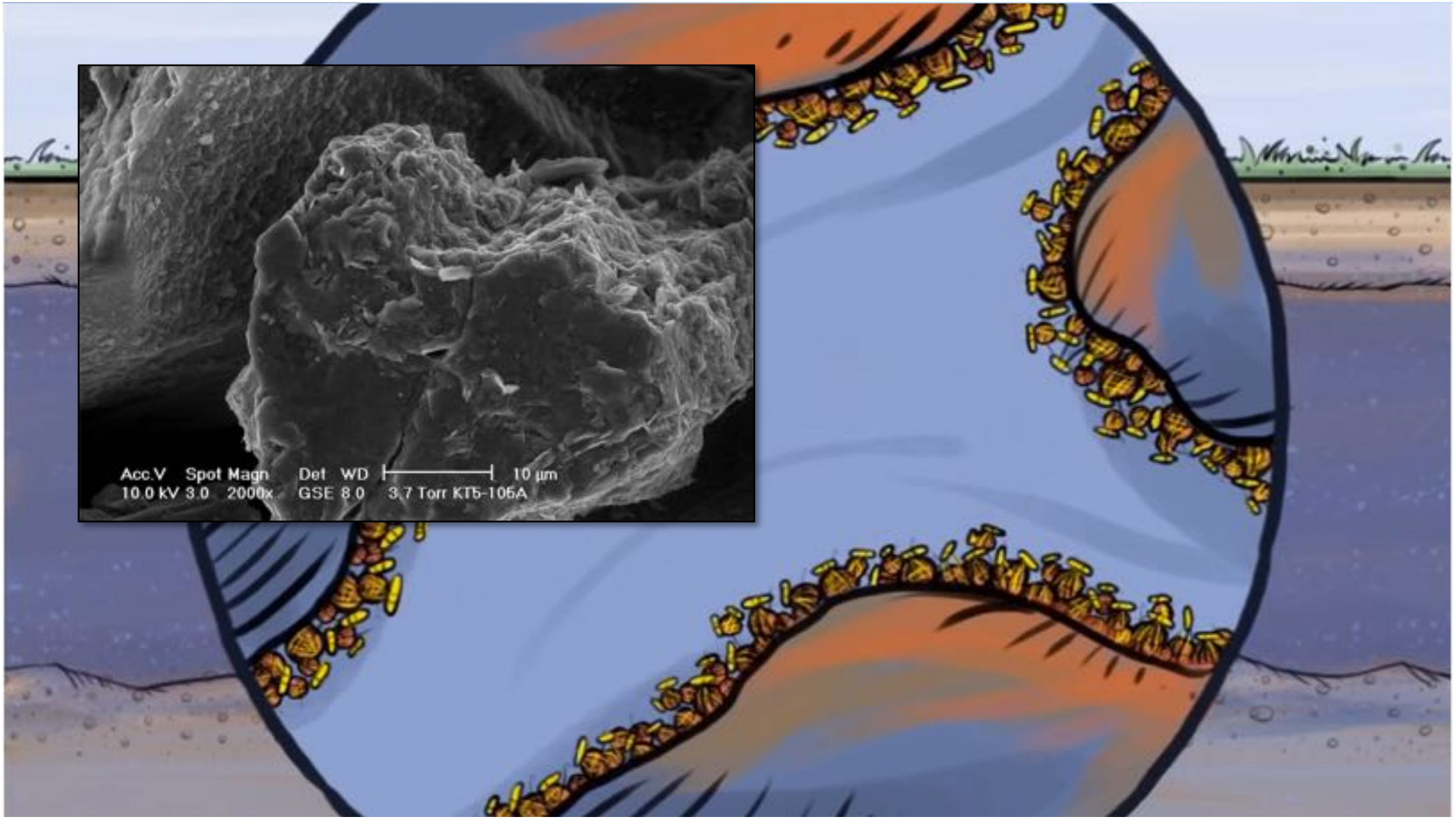
- A highly dispersive, injectable sorbent and microbial growth matrix
- Sorbent
  - Rapid drop in dissolved-phase contaminant concentration
  - Immediate risk-reduction
- Microbial growth matrix
  - Accelerated bio-destruction of sorbed mass
  - Ability to secure clean-up to much lower targets

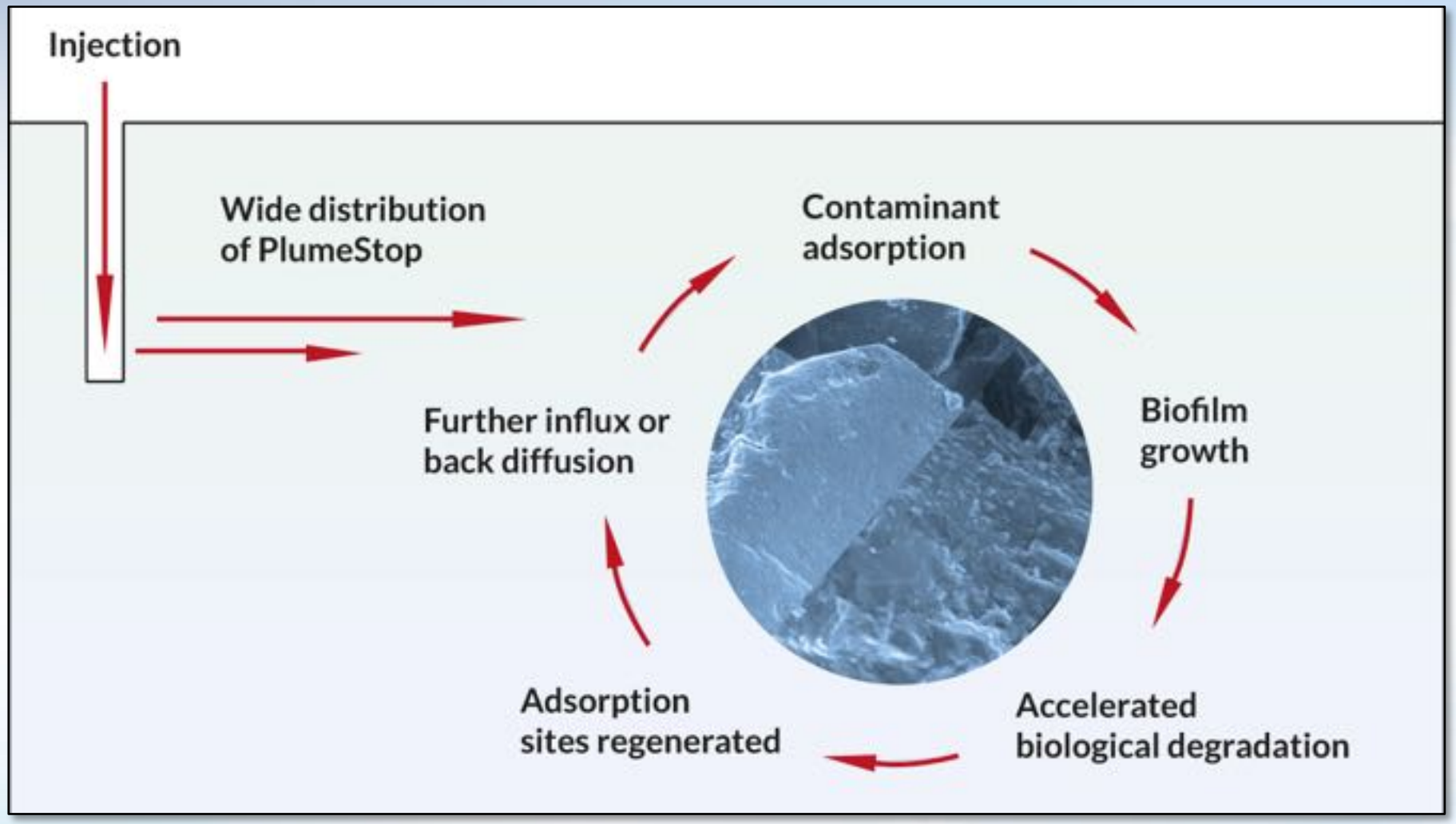
What the reagent is

PlumeStop™
LIQUID ACTIVATED CARBON™

- Colloidal activated carbon (1 – 2 µm)
  - Size of a bacterium – suspends as 'liquid'
  - Huge surface area – extremely fast sorption
- Proprietary anti-clumping / distribution supporting surface treatment (patent applied for)
  - Core innovation
  - Enables wide-area, low-pressure distribution through the soil matrix without clogging
- Low-solubility / controlled availability matrix nutrients
  - Support in-matrix contaminant biodegradation
  - Does not impact groundwater / eutrophication


PLUME STOP
Liquid Activated Carbon
Fracture-emplaced PAC
Dispersion-emplaced LAC


Acc.V Spot Magn Det WD 10 µm
10.0 kV 3.0 2000x GSE 8.0 3.7 Torr KT5-105A


Injection
Wide distribution of PlumeStop
Contaminant adsorption
Biofilm growth
Accelerated biological degradation
Adsorption sites regenerated
Further influx or back diffusion

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Liquid Activated Carbon

Example in Use
- Mixed Solvents -

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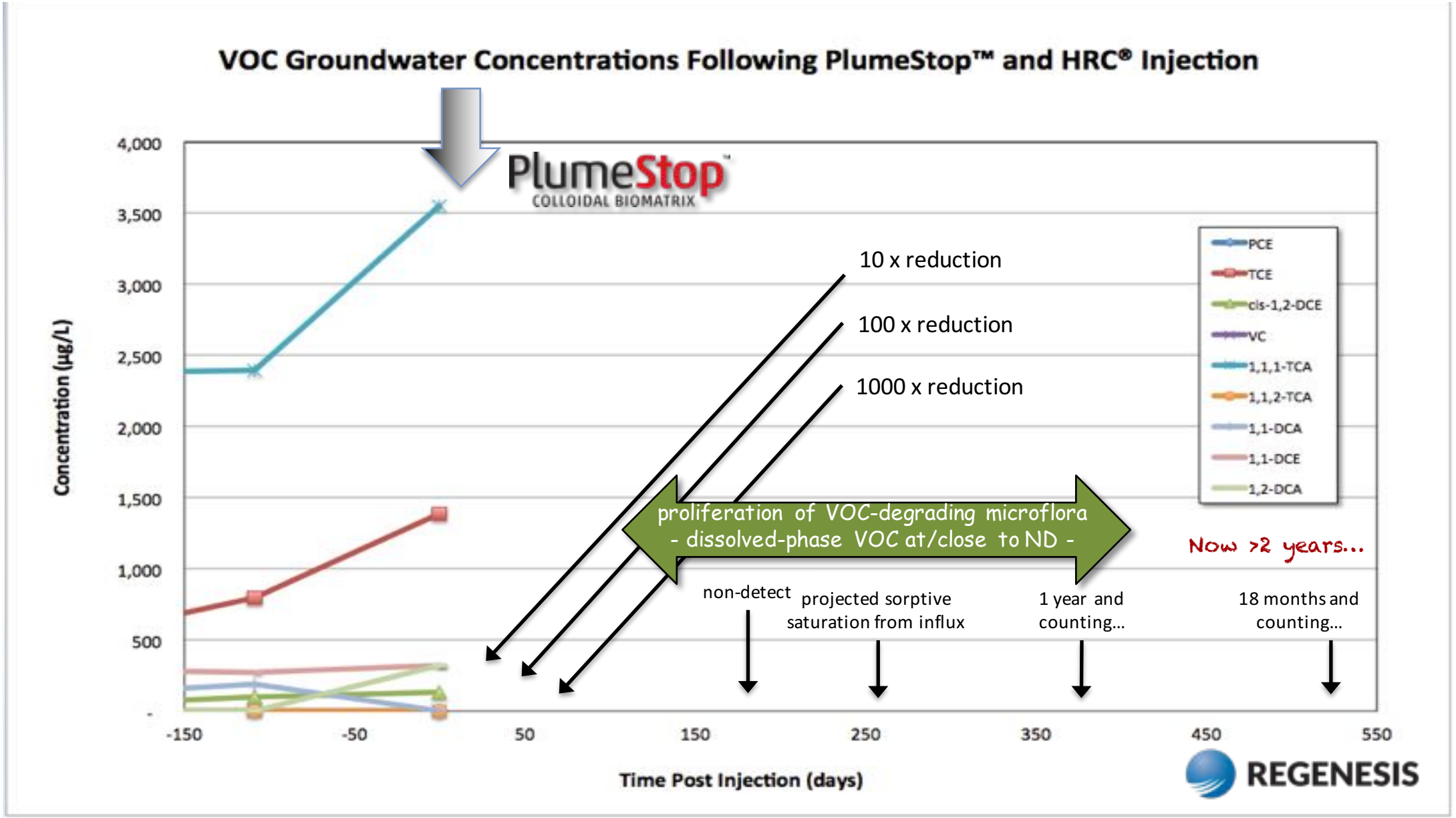
Case Study – Mixed VOC's

- Former electronics facility
  - TCE 1,390 µg/L
  - TCA 3,550 µg/L
- Sand to silty-sand
- Depth to groundwater 3 – 4 m
- Seepage velocity 3.7 m/yr to the southwest
- Test site injection of PlumeStop™ and HRC®


VOC Groundwater Concentrations Following PlumeStop™ and HRC® Injection
PlumeStop
COLLOIDAL BIOMATRIX
Concentration (µg/L)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
-150
-50
50
150
250
350
450
550
Time Post Injection (days)
10 x reduction
100 x reduction
1000 x reduction
proliferation of VOC-degrading microflora
- dissolved-phase VOC at/close to ND -
Now >2 years...
non-detect
projected sorptive saturation from influx
1 year and counting...
18 months and counting...
PCE
TCE
cis-1,2-DCE
VC
1,1,1-TCA
1,1,2-TCA
1,1-DCA
1,1-DCE
1,2-DCA
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Liquid Activated Carbon

- Distribution through Soil -

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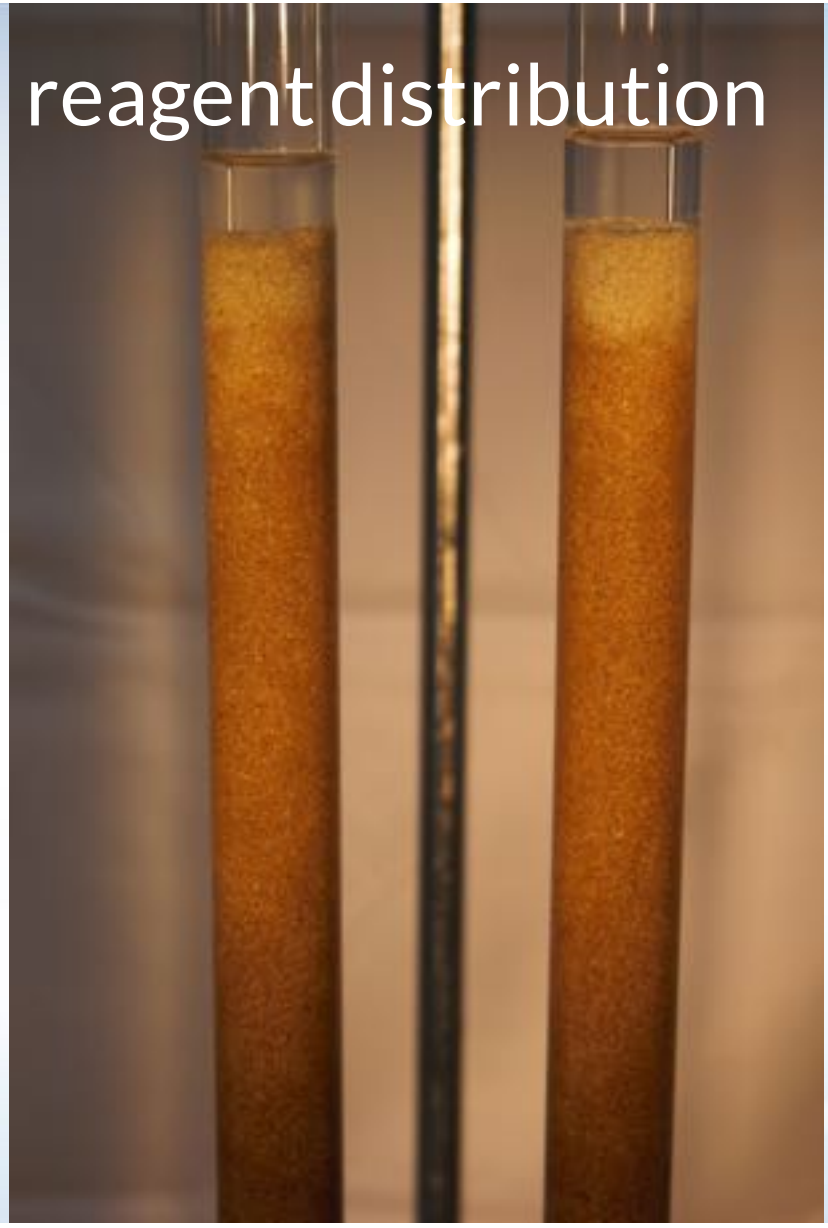
PlumeStop™: reagent distribution



PlumeStop

Powdered Activated Carbon

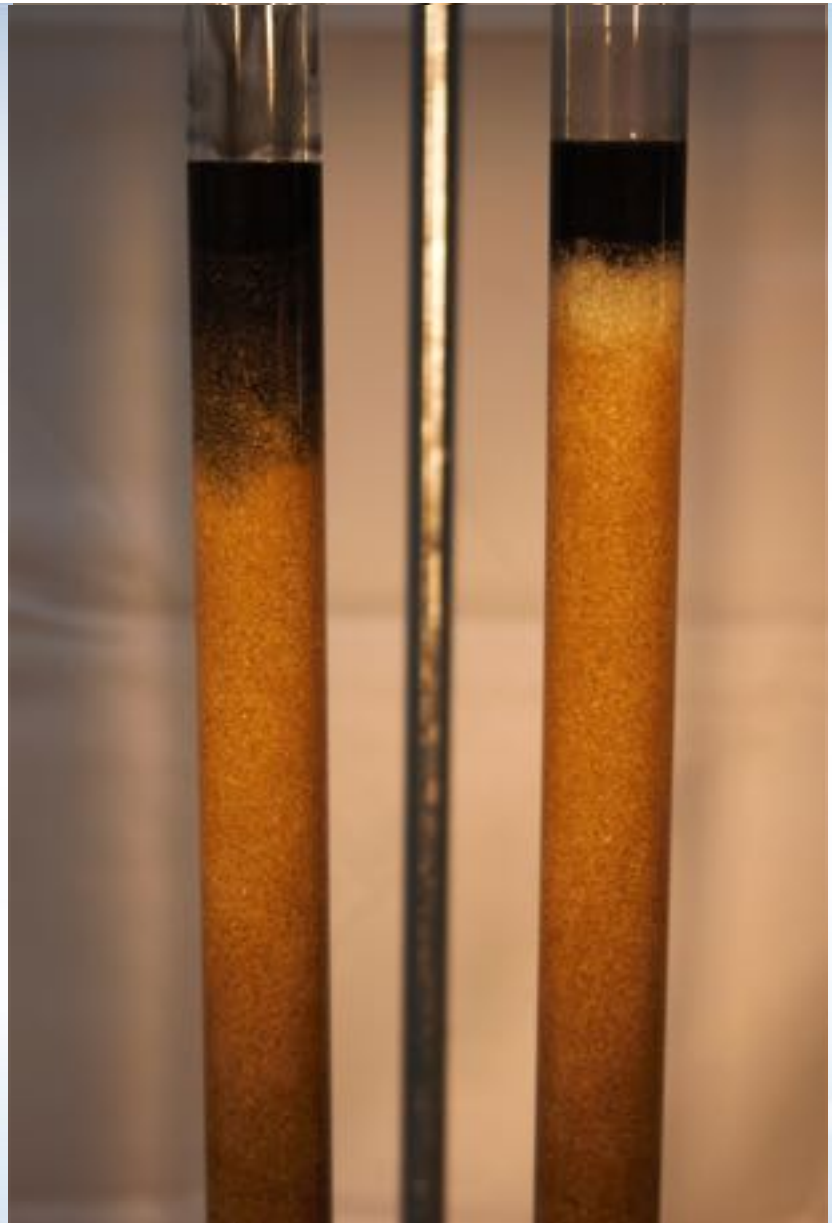
repeat

PlumeStop

Powdered Activated Carbon

repeat

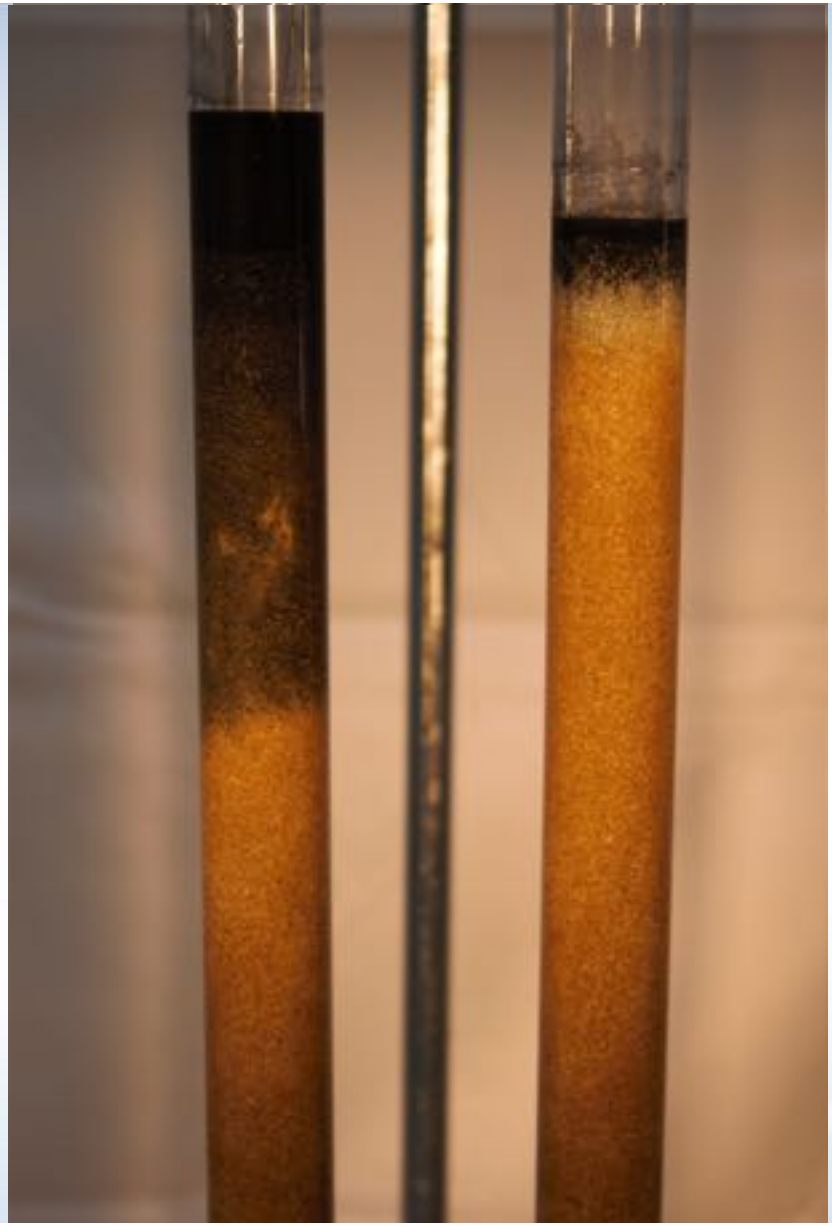
PlumeStop



Powdered Activated Carbon

repeat

PlumeStop



Powdered Activated Carbon

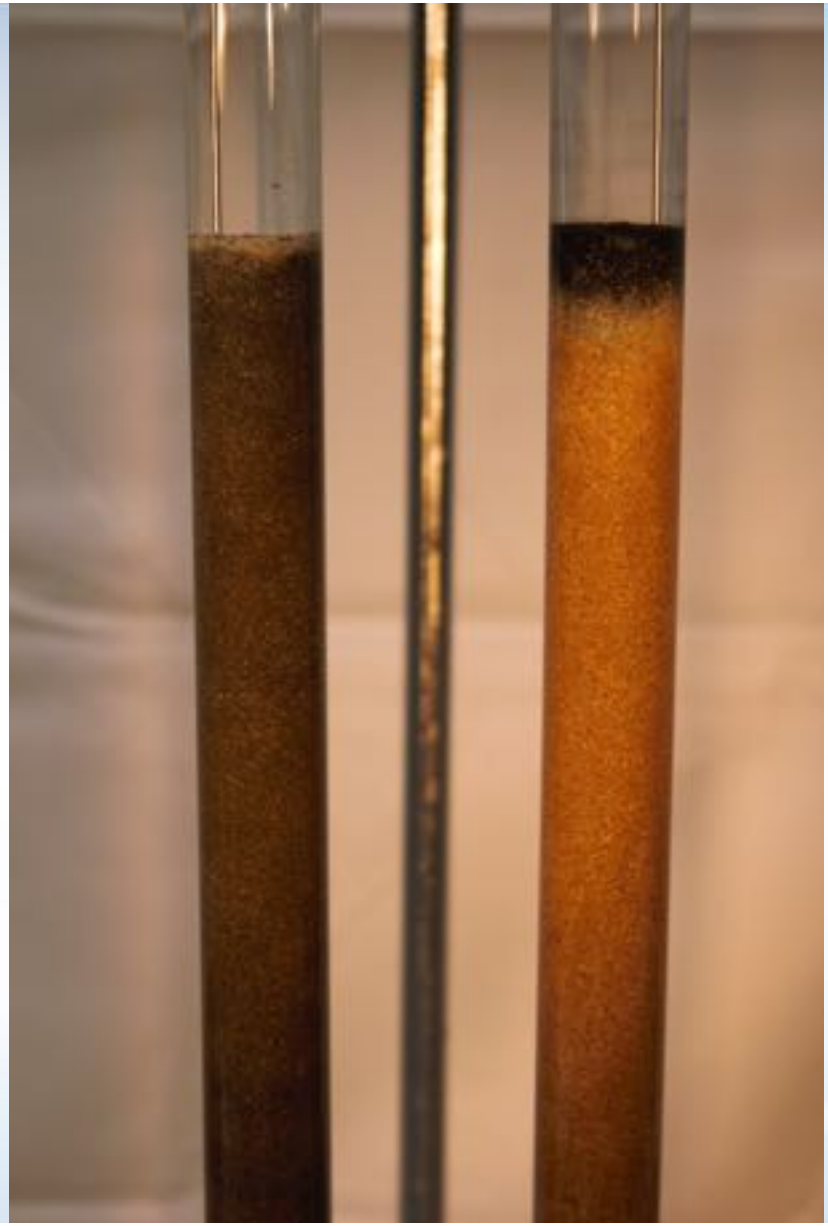
repeat

PlumeStop

Powdered Activated Carbon

repeat

PlumeStop

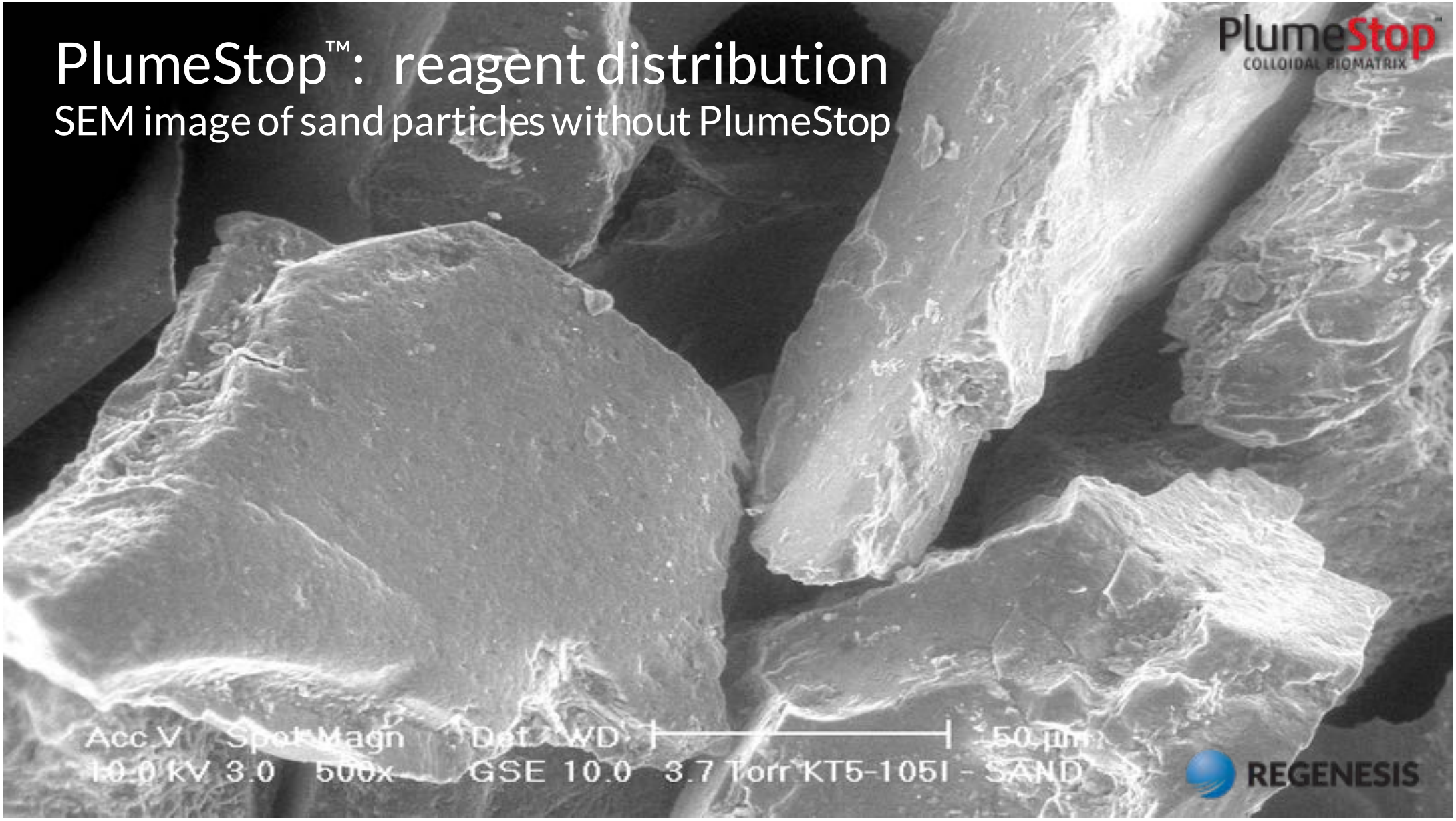


Powdered Activated Carbon

repeat

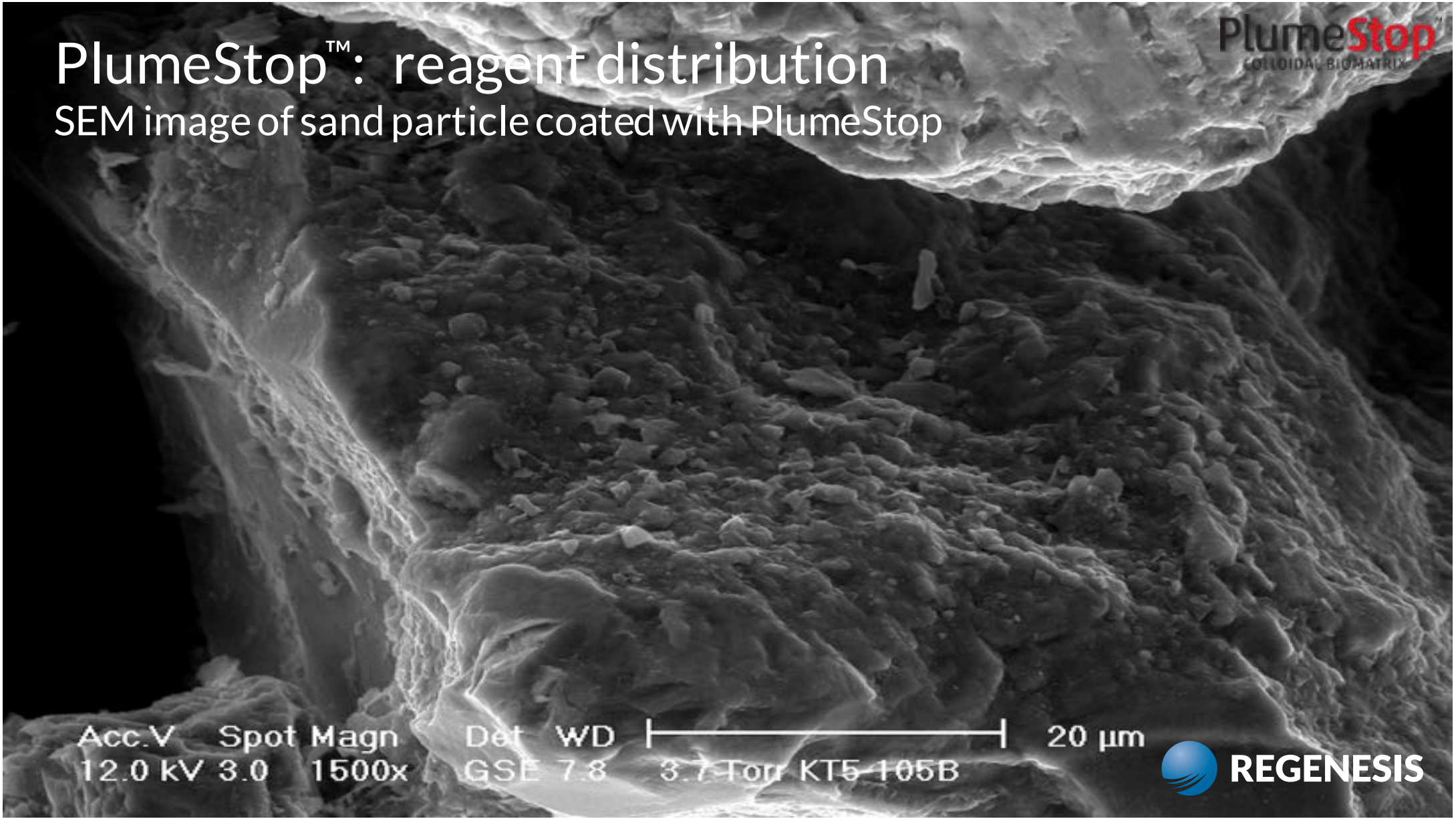
PlumeStop™: reagent distribution

SEM image of sand particles without PlumeStop

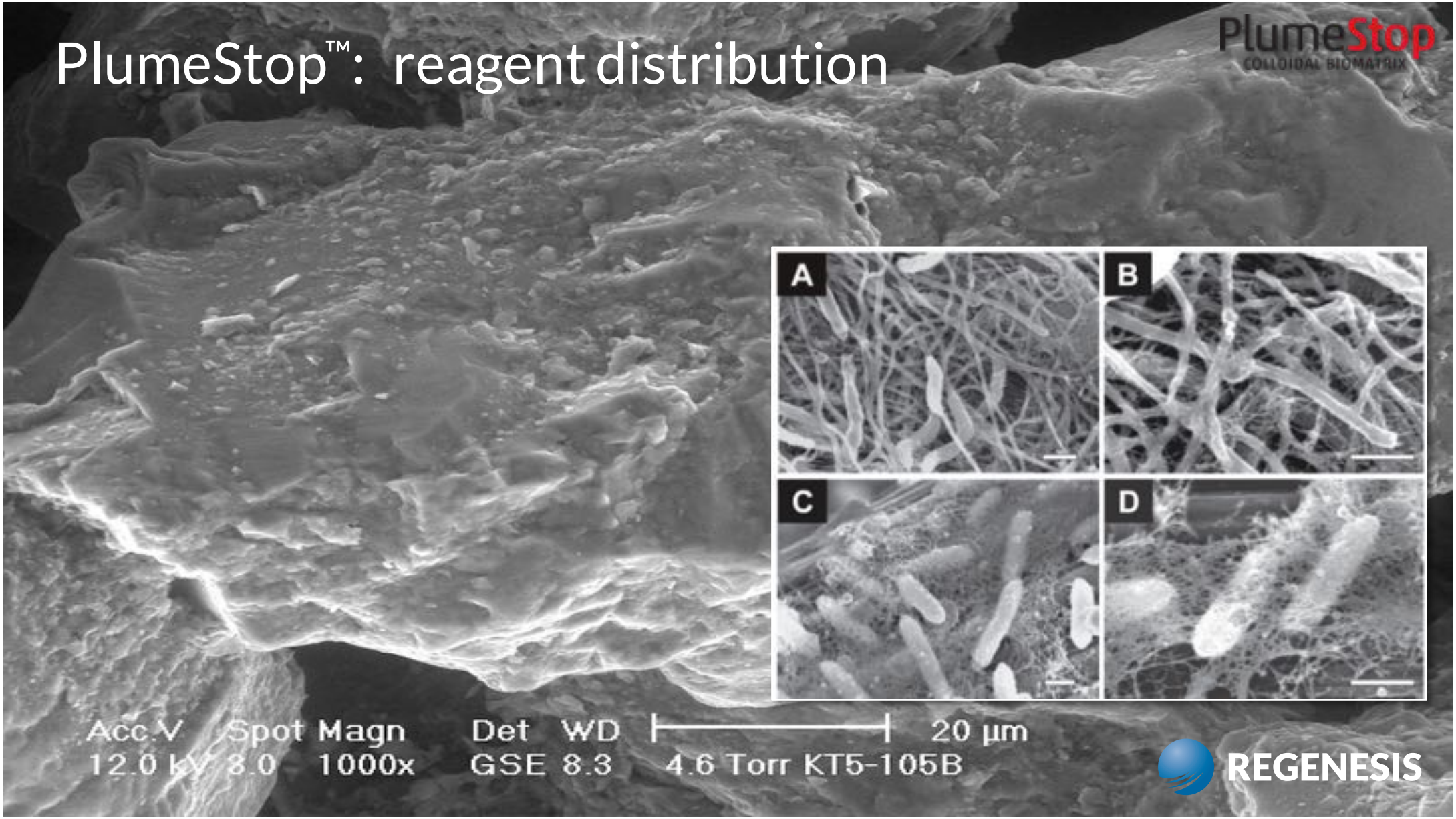


PlumeStop™: reagent distribution

SEM image of sand particle coated with PlumeStop



PlumeStop™: reagent distribution




16
12
8
4

PLUME STOP™
Liquid Activated Carbon

–performance –

chlorinated solvents – post-sorption degradation – lines of evidence

(skip to next)

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California Site
• Pilot test – single well
• Former dry cleaners
• Modest µg/L PCE residue

California Site

- ‘Dune Sand’ formation
- 10 m/year groundwater flow
- High redox conditions (aerobic)
- No attenuation evident

- PCE 550 µg/L
- No daughter products
- PlumeStop™
- Electron donor and bacteria

Pilot Test Arrangement

MW-3 (ppb)

Historic Data

Year	PCE	TCE	VC	1,2 Cis	VC
2001	156	0	0	0	0
2002	94	0	0	0	0
2002.5	242	0	0	0	0
2003	174				0
2004	147				0
2005	122				0
2006	203				0
2007	584				0
2008	310				0
2009	587				0
2010	330	0	0	0	0
2011	501	0	0	0	0
2012	499	0	0	0	0

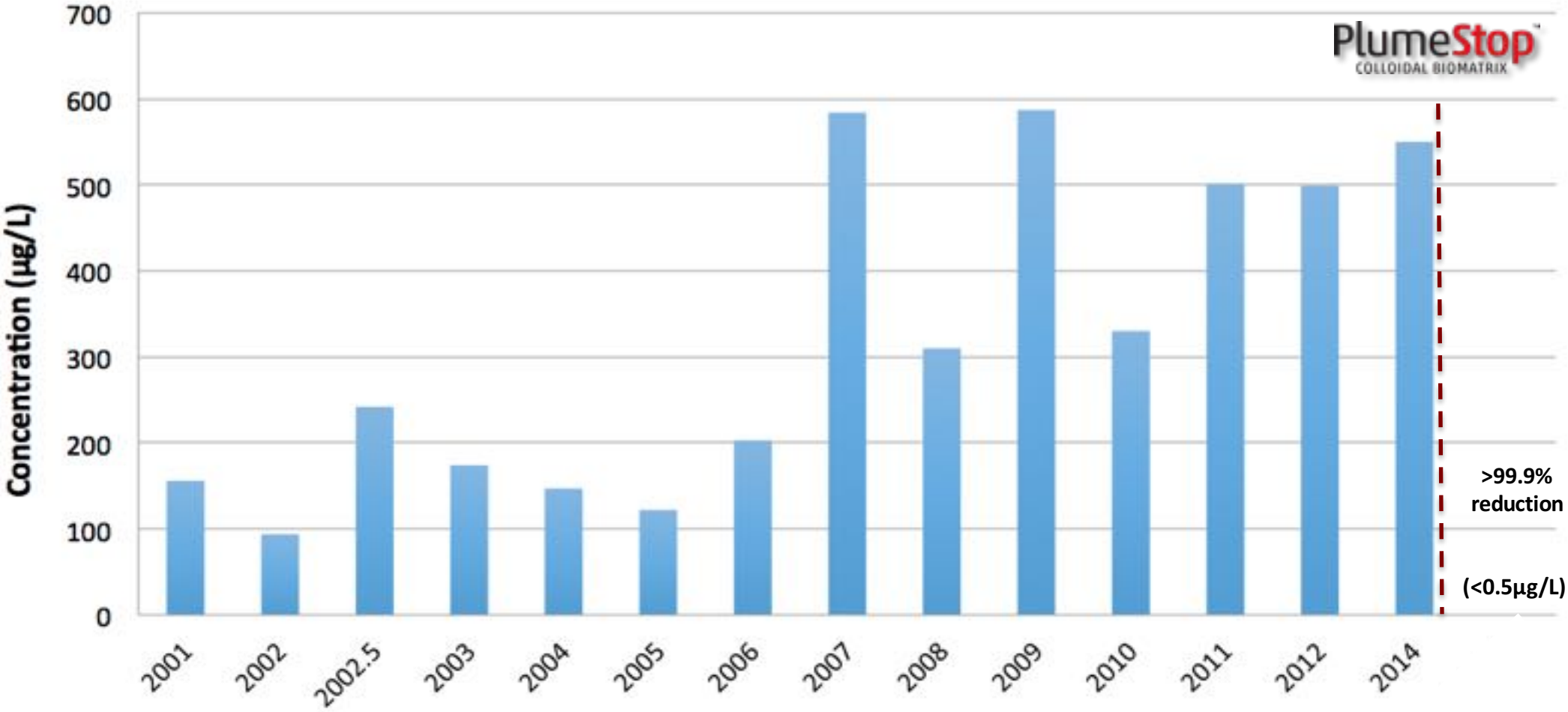
Steadily increasing PCE

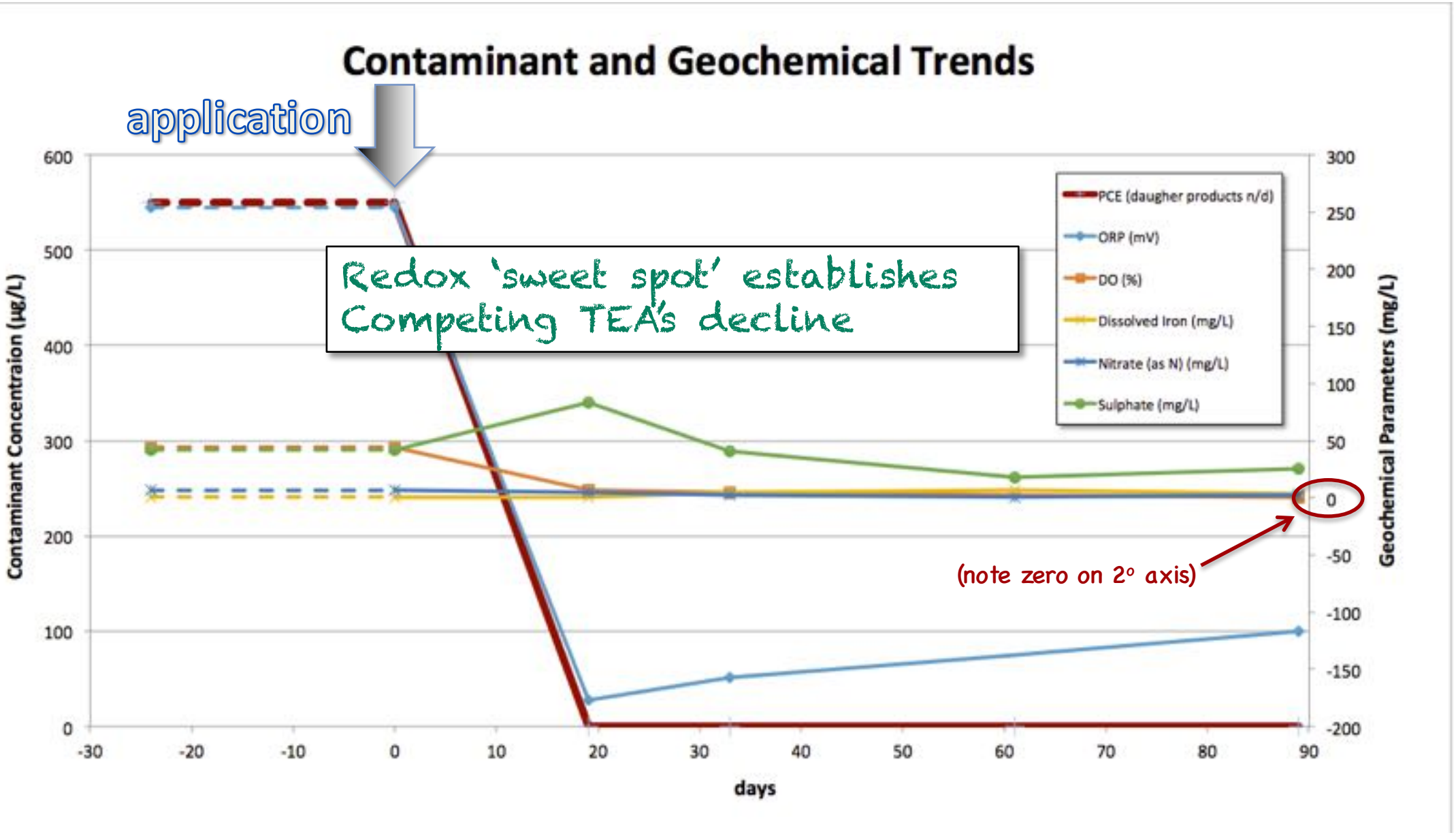
No daughter products

(aerobic conditions)

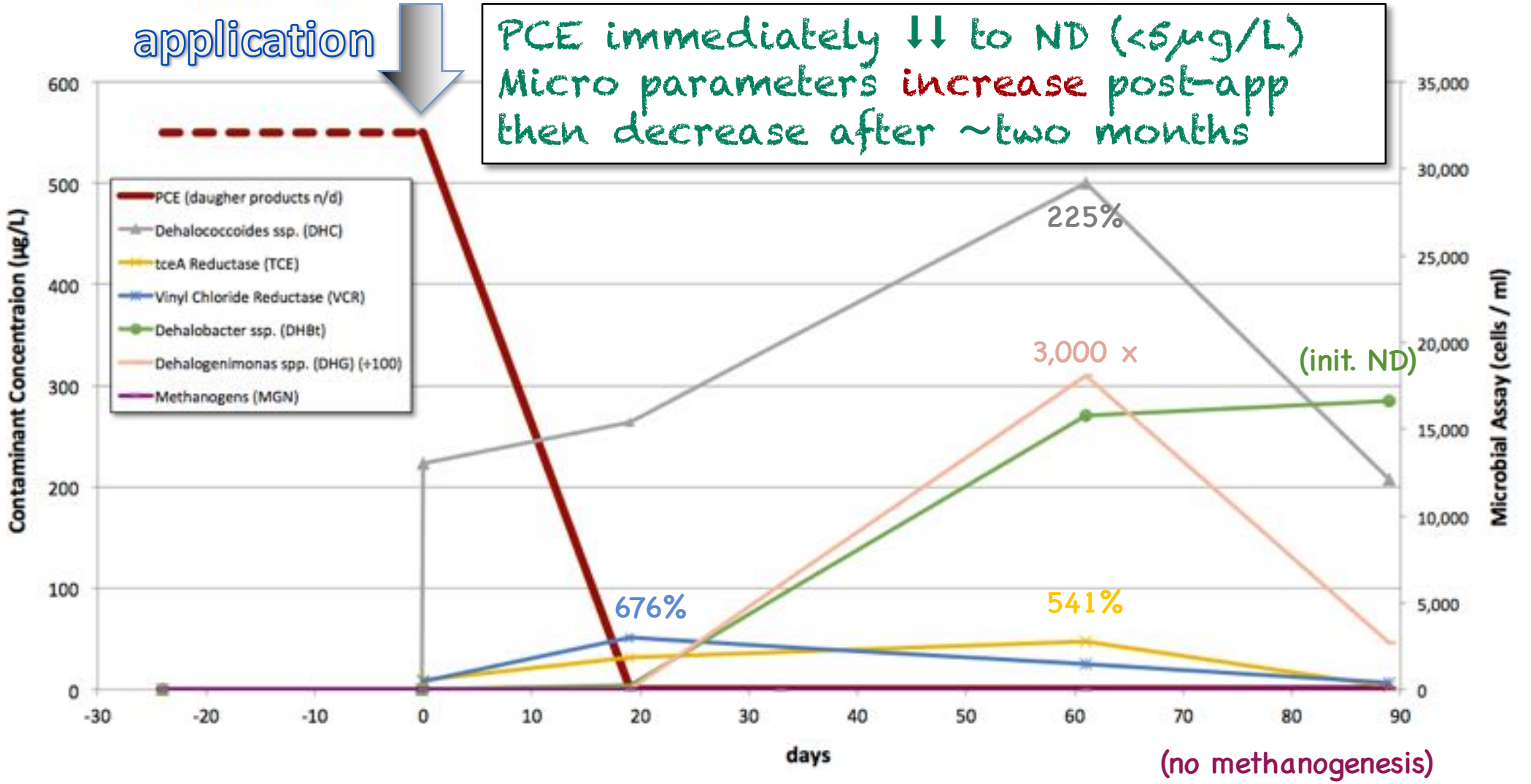
PCE Concentration Trends

(daughter products and other VOCs non-detect)



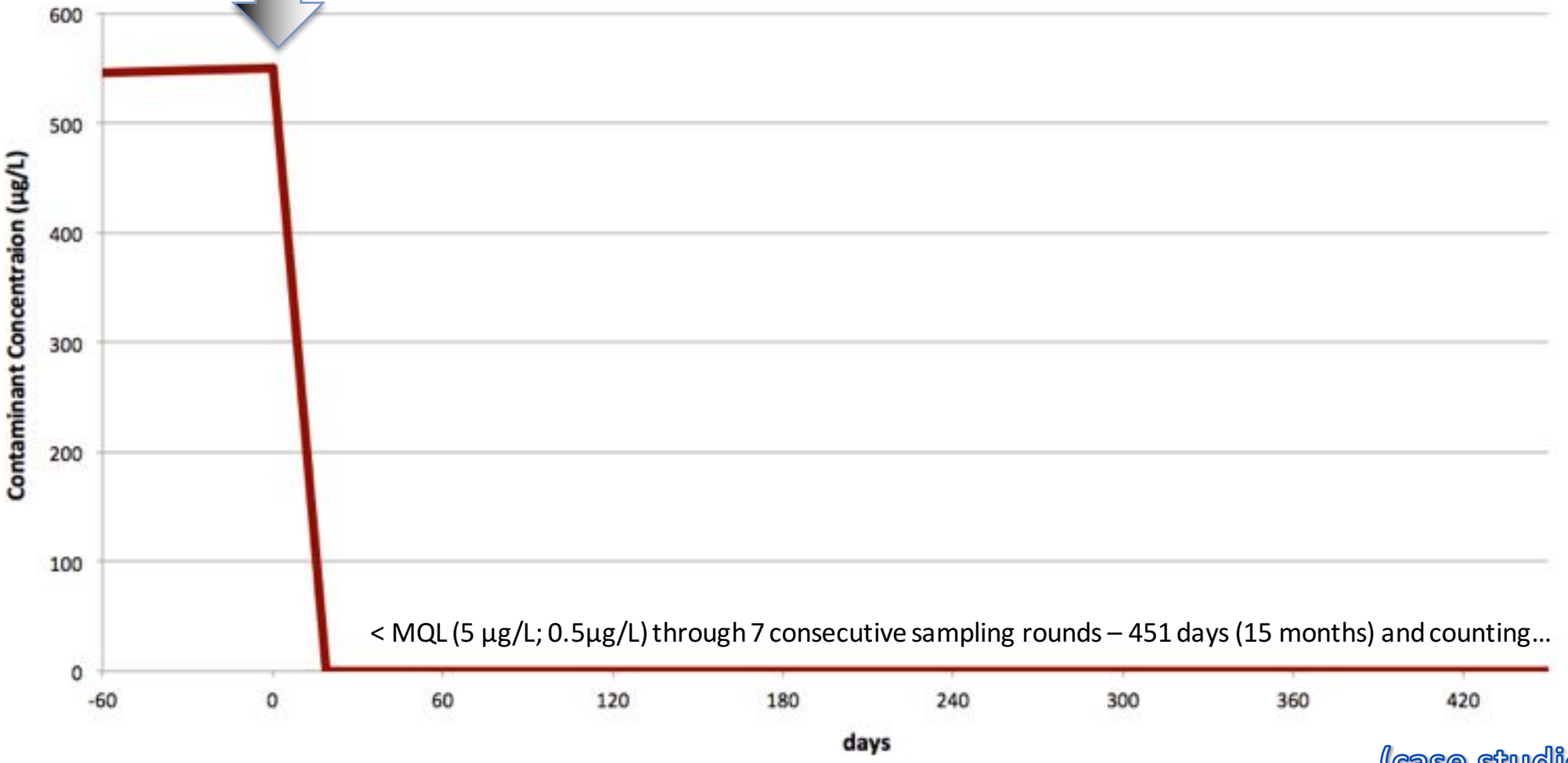

Contaminant and Geochemical Trends
application
Redox 'sweet spot' establishes
Competing TEA's decline
PCE (daugher products n/d)
ORP (mV)
DO (%)
Dissolved Iron (mg/L)
Nitrate (as N) (mg/L)
Sulphate (mg/L)
(note zero on 2° axis)
Contaminant Concentraion (µg/L)
Geochemical Parameters (mg/L)
days
600
500
400
300
200
100
0
300
250
200
150
100
50
0
-50
-100
-150
-200
-30
-20
-10
0
10
20
30
40
50
60
70
80
90

Contaminant and Dechlorination Microbial Assay Trends



application

Longer Term: PCE Post-PlumeStop (daughter products non detect)



(case studies)

PLUME STOP™

Liquid Activated Carbon

- commercial projects -

(close)

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Case Study
- Inner-City Development / Time Pressure -

Downtown Chicago

(skip) (close)

Case Study: Inner City Development – Time Pressure

- Neighborhood of McCormick Place – Central Chicago
  - New Sports Stadium
  - New Hotel Complex

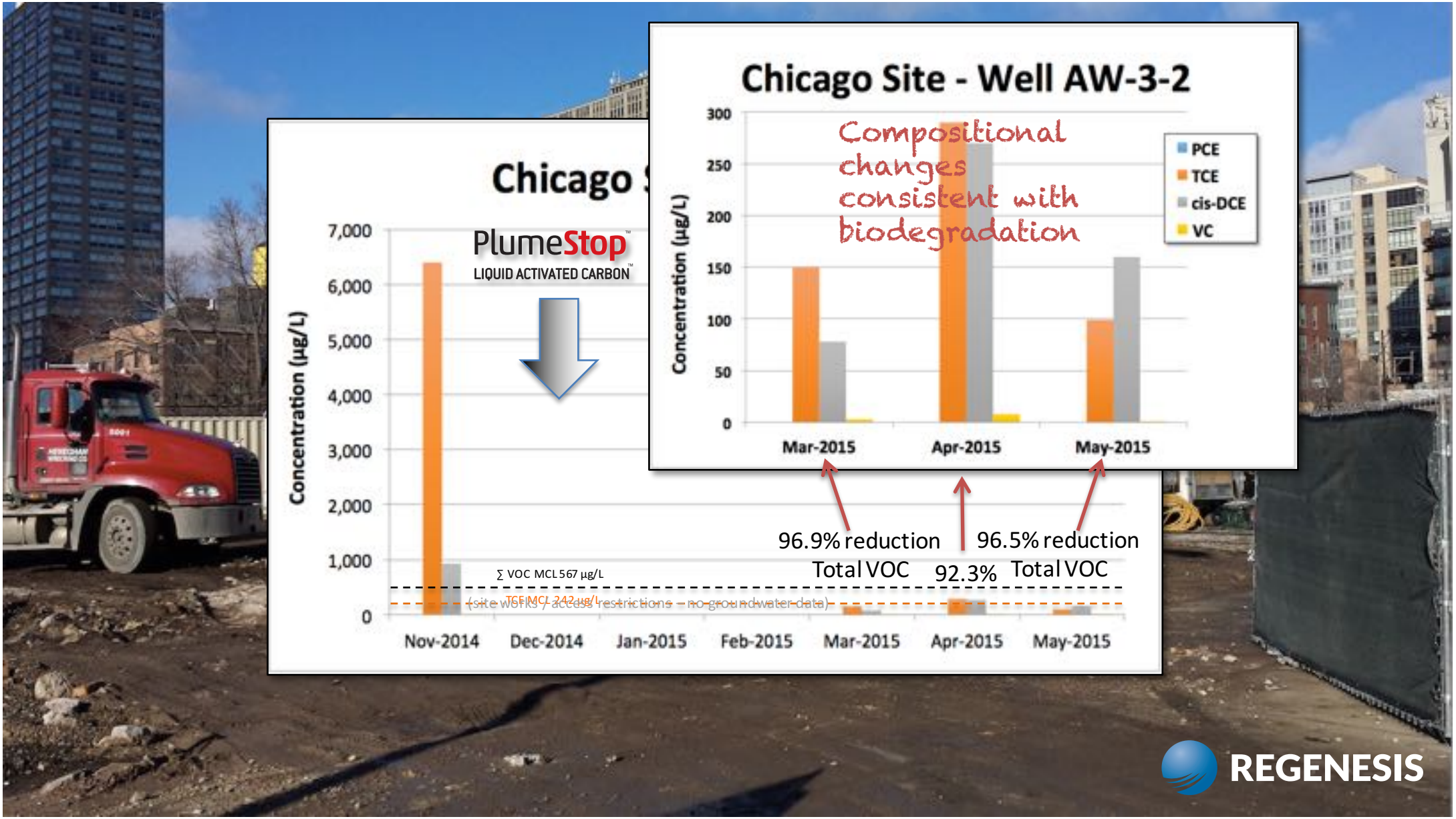
- Solvent residues
- Tight time window
- High cost implications of delay
- Key remediation requirement: **FAST**

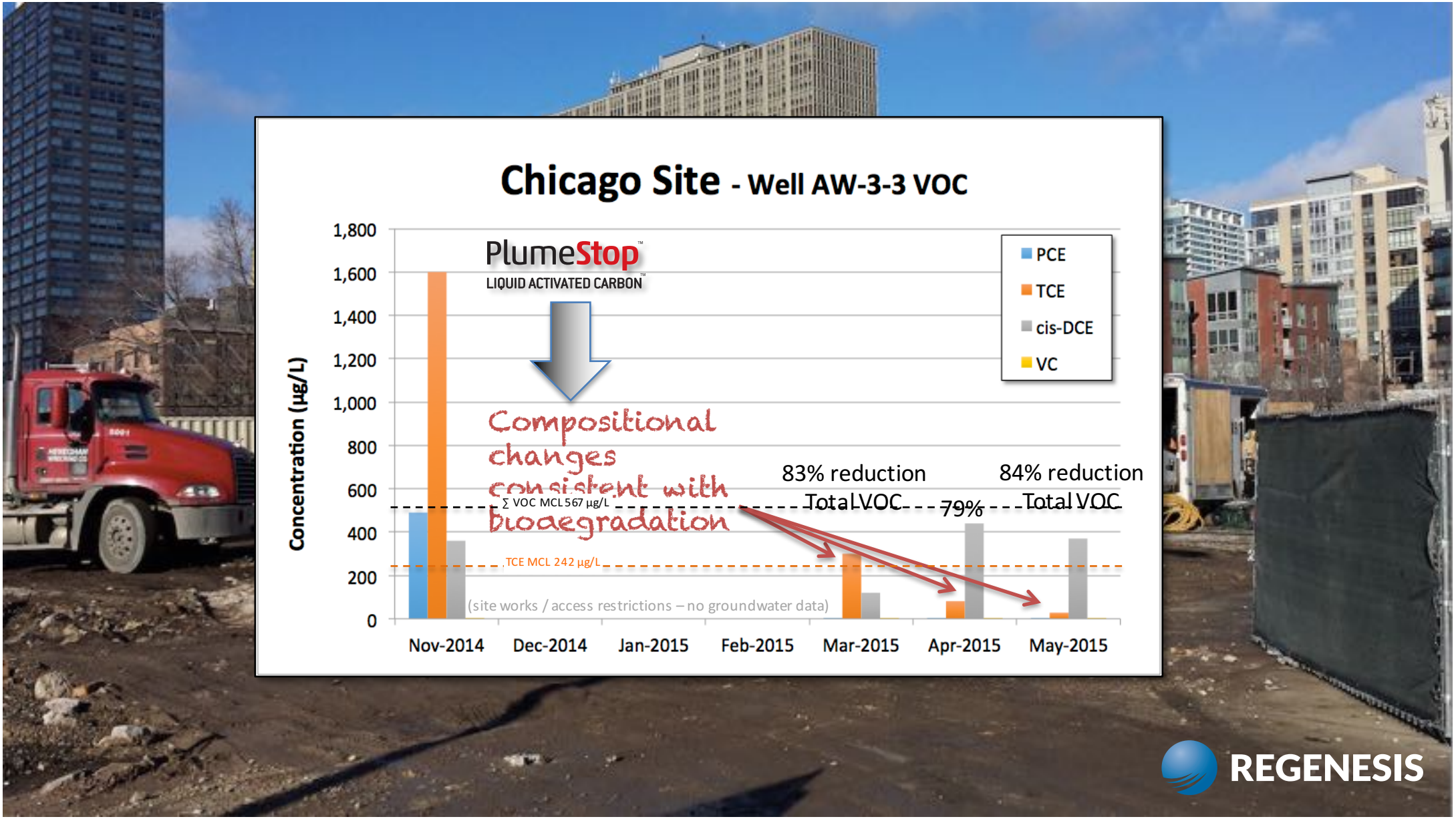
Case Study: Inner City Development – Time Pressure

- Why the tight time window?
  - Weren't the solvent residues known?
- Access restrictions – historic buildings
  - Precluded early start
- Problem was moved aside

Case Study: Inner City Development – Time Pressure

- PCE and TCE residues – up to 7,440 µg/L
- Sand formation over clay
  - Treatment area 300 m x 500 m – (1,000' x 1,600')
  - Treatment Zone 3 – 7 mbgl - (10' – 22')
- Enhanced bio: HRC®, BDI®
  - Sufficient to address the contamination
- PlumeStop™
  - Rapid risk reduction and bio process acceleration
  - Take the bio process out of the groundwater phase
- 19 days' fieldwork on site (Chicago winter)
  - 138 direct-push injections – no resident equipment


Chicago Site - Well AW-3-2
Compositional changes consistent with biodegradation
PCE
TCE
cis-DCE
VC
Concentration (µg/L)
300
250
200
150
100
50
0
Mar-2015
Apr-2015
May-2015
Chicago
PlumeStop
LIQUID ACTIVATED CARBON
Concentration (µg/L)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
∑ VOC MCL 567 µg/L
TCE MCL 242 µg/L
(site works / access restrictions – no groundwater data)
Nov-2014
Dec-2014
Jan-2015
Feb-2015
Mar-2015
Apr-2015
May-2015
96.9% reduction Total VOC
92.3%
96.5% reduction Total VOC
REGENESIS


Chicago Site - Well AW-3-3 VOC
PlumeStop
LIQUID ACTIVATED CARBON
Concentration (µg/L)
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
PCE
TCE
cis-DCE
VC
Compositional changes consistent with bioaegradation
∑ VOC MCL 567 µg/L
TCE MCL 242 µg/L
83% reduction Total VOC
79%
84% reduction Total VOC
(site works / access restrictions – no groundwater data)
Nov-2014
Dec-2014
Jan-2015
Feb-2015
Mar-2015
Apr-2015
May-2015
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Chicago Site - Status

- Rapid reduction in groundwater contamination
  - 80 – 97% from first sampling interval (total solvents)

- Bio conditions established (redox, TOC, microbial numbers)
  - Parent/daughter compound ratio shifts (dissolved phase)
  - (consistent with biodegradation)

- ∑VOC targets met – from first sampling round (through all rounds)
- TCE targets met – from second sampling round (and degrading fast)
- Completion report submitted (June 2015)
- No further action required

Thank You

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PLUME STOP™

Liquid Activated Carbon

- usage indicators -

(close)

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PlumeStop™ – product usage indicators

1. When time is critical
2. To secure stringent clean-up targets
3. For passive control of migrating contamination
4. As a long–term means of addressing matrix back-diffusion

(skip detail)

PlumeStop™ – product usage indicators

1. When time is critical

The fastest groundwater remediation technology available today?

- Immediate risk reduction secured through sorption
  (especially fast due to high relative surface area and wide dispersion)
- Long-term destruction secured through in-matrix biodegradation
  (accelerated degradation achieving bio-regeneration of sorption sites)

PlumeStop™ – product usage indicators

2. For securing stringent clean-up targets

- Low µg/L targets are challenging for all technologies
- Bio typically performs comparatively well, but at very low concentrations, substrate availability becomes insufficient to support microbial activity
- PlumeStop accumulates low-level contaminants into the bio-matrix until concentrations **become sufficient within the matrix** to support an active microflora while keeping contaminants out of the groundwater

PlumeStop™ – product usage indicators

3. Passive control of migrating diffuse contamination

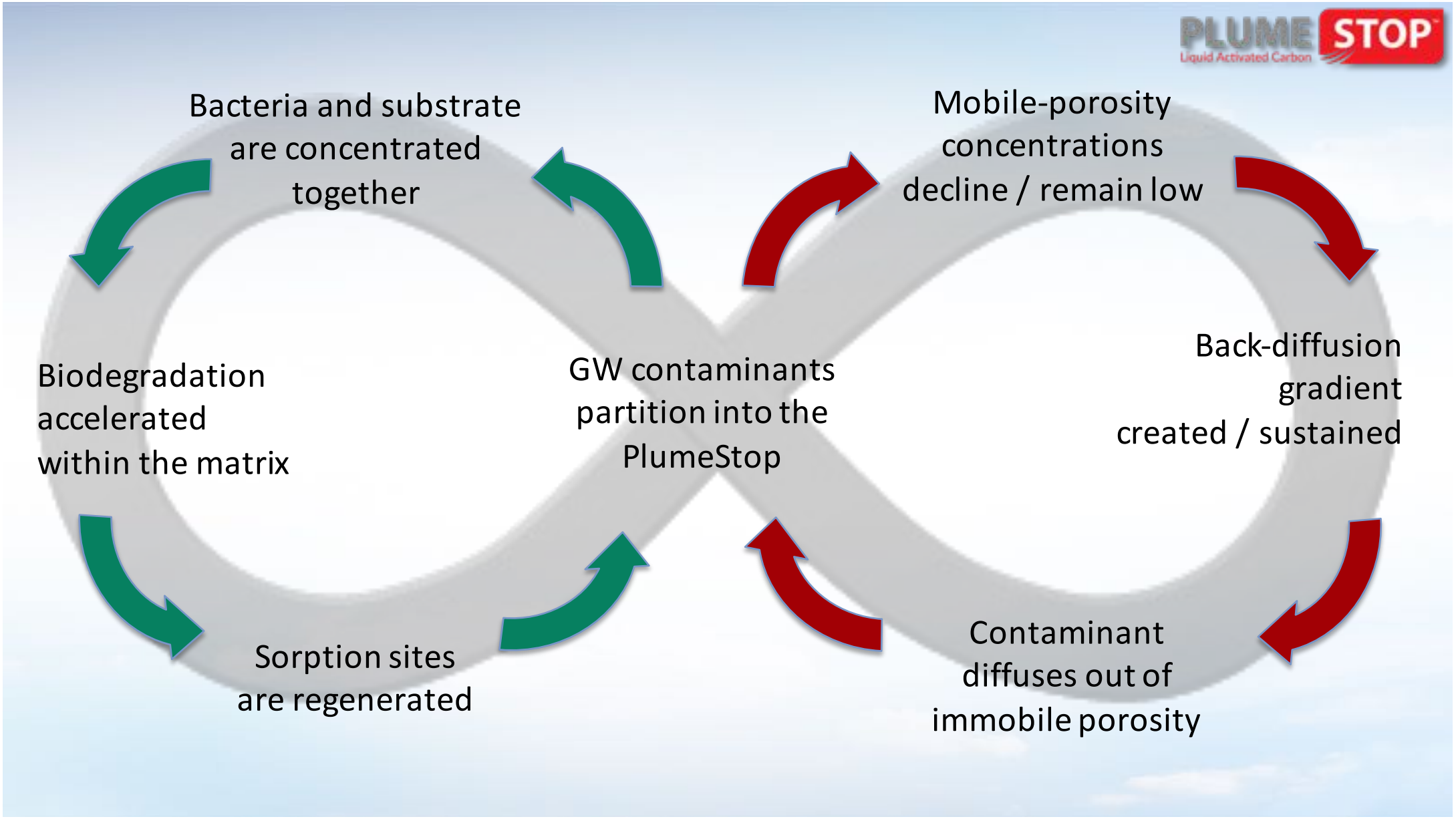
Used in barrier formation to capture diffuse contaminants

- Concentration of contaminants in matrix for locally intensive treatment
- Tighter capture zone than bio-barriers alone
  (especially valuable where space is limited and/or groundwater is fast-flowing)
- Faster destruction rates and greater timing tolerance between (bio) amendment applications – if still needed

PlumeStop™ – product usage indicators

4. A long–term means of addressing matrix back-diffusion
   (i.e. diffusion-driven rebound)

- PlumeStop maintains a concentration gradient out of the immobile porosity
- Mobile porosity contaminant conc. remains low due to capture by PlumeStop
- Sorption sites regenerate due to accelerated in-matrix biodegradation
- The product is not consumed and remains functional – theoretically for decades


PLUME STOP
Liquid Activated Carbon
Bacteria and substrate are concentrated together
Mobile-porosity concentrations decline / remain low
Biodegradation accelerated within the matrix
GW contaminants partition into the PlumeStop
Back-diffusion gradient created / sustained
Sorption sites are regenerated
Contaminant diffuses out of immobile porosity

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PLUME STOP™
Liquid Activated Carbon

up-front orders of magnitude reduction and accelerated bio-destruction
using a dispersive injectable reagent

Questions?

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Thank You

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