Sequester and Destroy: A Multi-Site Performance Review of Liquid Activated Carbon for Groundwater Treatment

Maureen Dooley

REGENESIS
Technology-Based Solutions for the Environment

REGENESIS

Outline

- Introduction
- Background on Technology Development
- Technology Functionality Basics
- Field Performance
- Case Studies
- Q&A

REGENESIS

REGENESIS

- Regenesis Remediation Products Division
- Land Science Technology

REGENESIS

Combined Remedies

All remediation technologies have strengths and weaknesses. These are different from one technology to another. Employing technologies in suitable combination can enable strengths to be combined and weakness overcome. This in turn can increase efficiency, improve performance, and thereby save time, money and resources.

REGENESIS

Reactive

Required technology change needed due to new conditions, technology limitations, time constraints and/or financial limitations.

- Inability to meet targets with in intended time frame
- Targets may have changed (e.g. lower) so original technology choice may not be suitable
- Site Conditions (unknown source)
- Change to Future Use (industrial vs residential)
- New advances
- Costs

REGENESIS

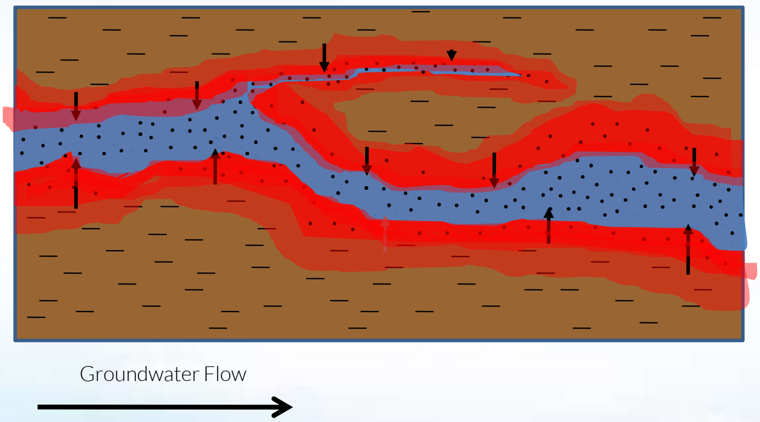
Remediation technologies

- Remediation technology categories
- physical (extraction/excavation/sorption),
- chemical (ISCO/ISCR) and
- biological (ENA/MNA).

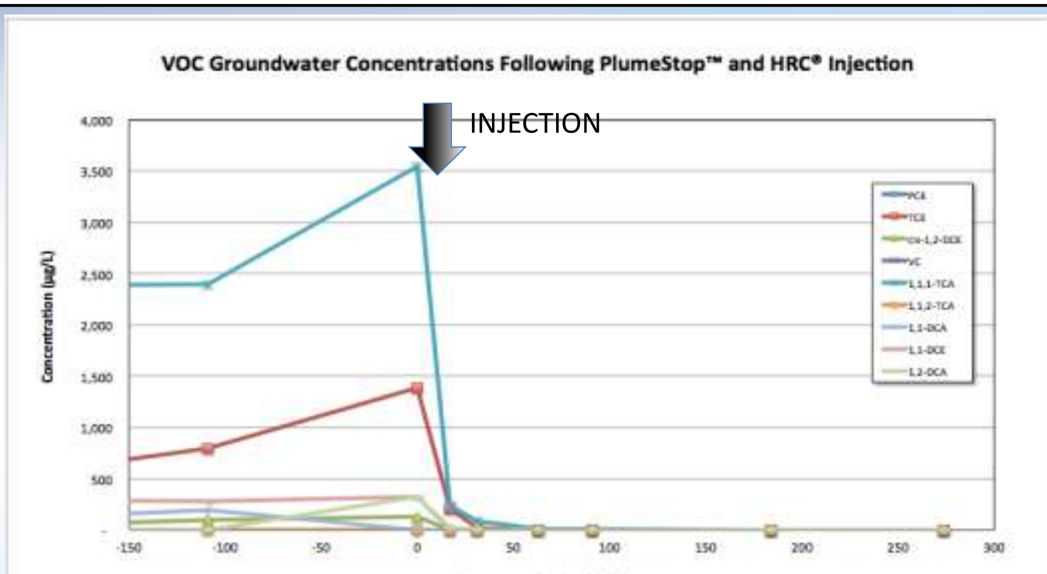
REGENESIS

Heterogeneous Aquifer Model

Upon Flushing and Removal of Adsorbed Mass "Back Diffusion" Continues

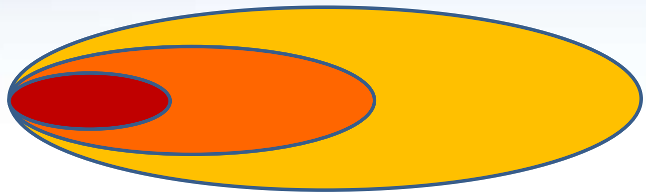


Challenges
- Meet Low Targets
- Rebound
- Remediation Time



©2015 All Rights Reserved. REGENESIS and REGENESIS product(s) are registered trademarks of REGENESIS Remediation Products.

Anatomy of a Groundwater Plume



Source Area:
Dig & Dump
Thermal
AS/SVE
ISCO
Stabilization

→

Core Plume Area:
ISCO
Bioremediation
Pump & Treat
PlumeStop

→

Dissolved Plume Area:
Bioremediation
Natural Attenuation
ISCO
PlumeStop

Contaminant Concentration

REGENESIS

The Reagent – what it is

PLUME STOP Liquid Activated Carbon

- A highly dispersive, injectable sorbent and microbial growth matrix
- 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

REGENESIS

PlumeStop

Powdered Activated Carbon

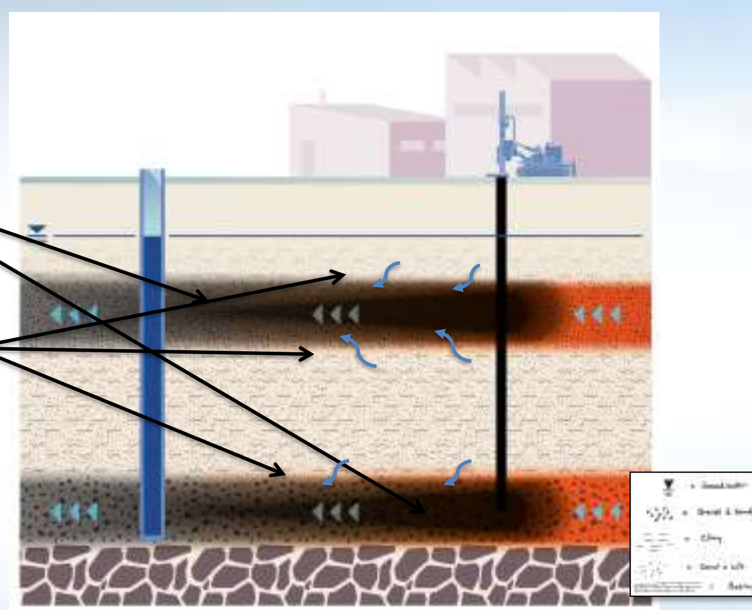
repeat

REGENESIS

PlumeStop Injection

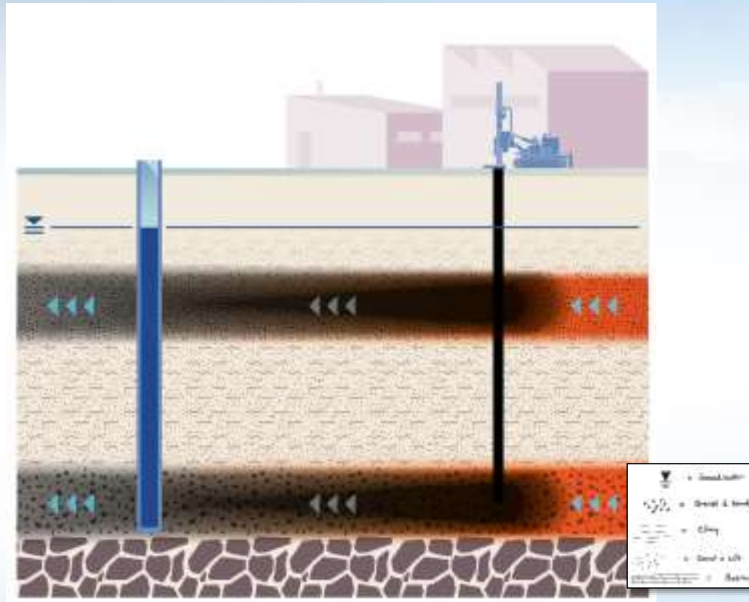
PlumeStop® flows into the subsurface at low pressure - coating the principle flux channels

Contaminant mass back-diffusing from the low-perm zones is captured
∴ Low & high perm zones are addressed



REGENESIS

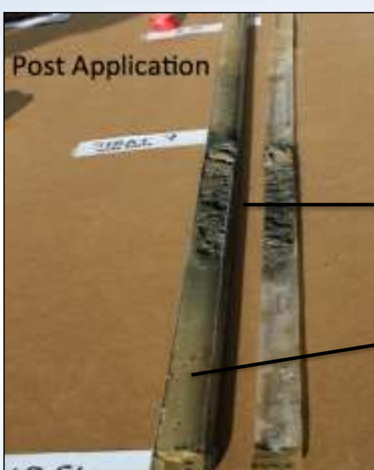
PlumeStop Injection

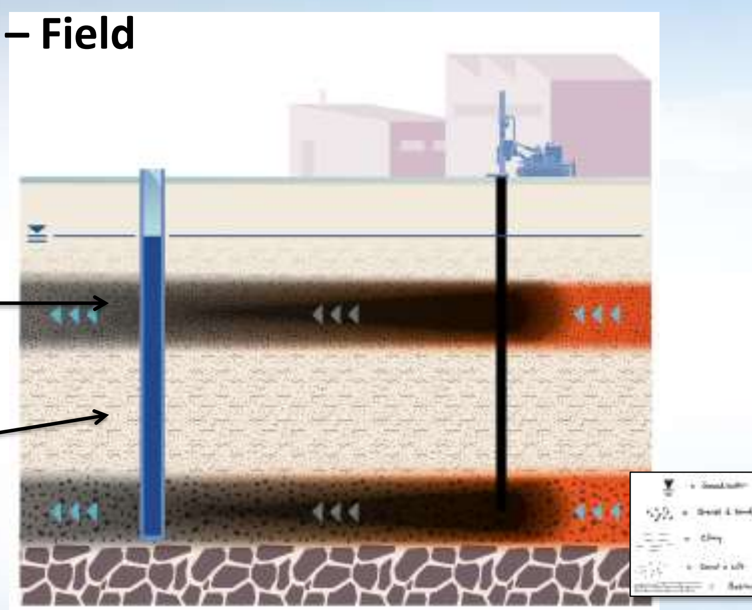


Distance / radius progressed depends on volume injected

REGENESIS

PlumeStop Injection – Field





REGENESIS

Tank set up with alternating high and low k zones. Low k = $1x10^{-4}$ cm/sec

Day 2

Day 53

REGENESIS -

REGENESIS

Tank Study

Tank #	Description of Treatment Condition
1	TCE control: Water flushing only, no amendments
2	PlumeStop Treatment: The only amendment applied was PlumeStop Liquid Activated Carbon
3	ERD Treatment: The tank was treated with an electron donor (sodium lactate) and was bioaugmented with a culture of *Dehalococcoides sp.* (DHC, BDI Plus)
4	PlumeStop + ERD Treatment: The tank was treated with PlumeStop and an electron donor (sodium lactate) and was bioaugmented with a culture of DHC (BDI Plus)

REGENESIS

Post PlumeStop injection

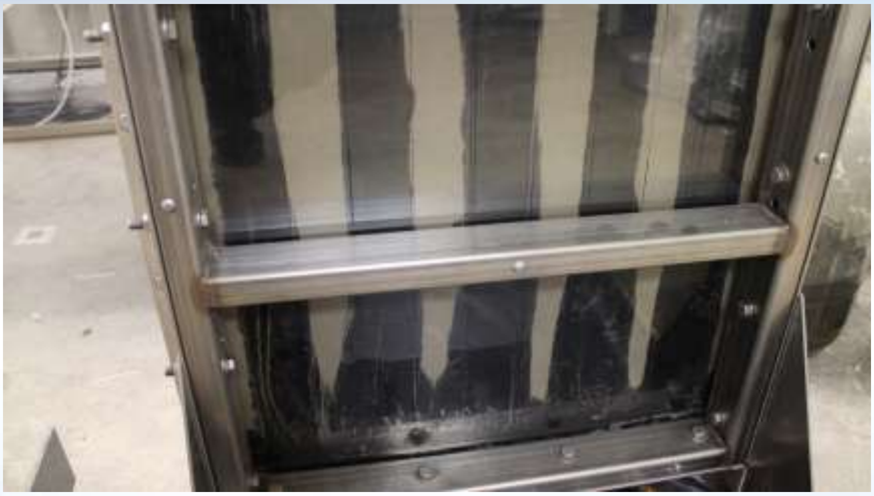
Day 2

Day 53

REGENESIS -

Top – Day 2

REGENESIS

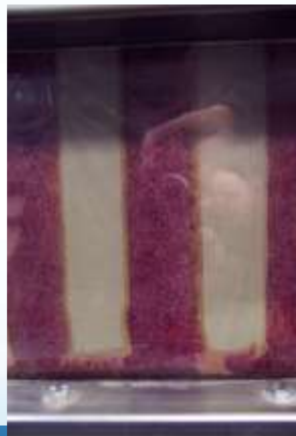


Bottom –
Day 2

Day 53

POTASSIUM PERMANGANATE

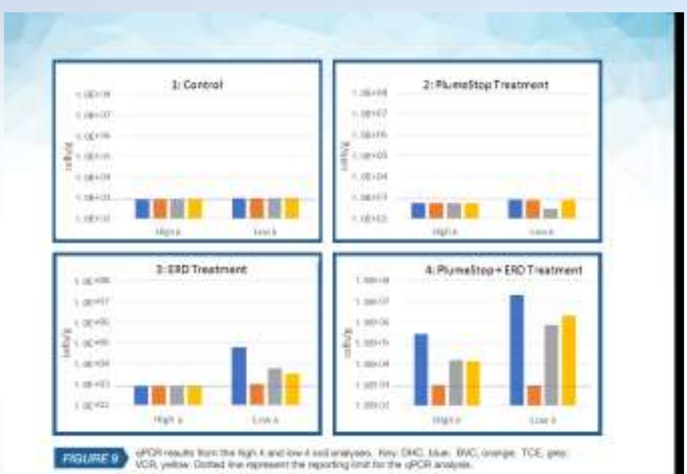
- During treatment:



Treatment of Contaminants in Low Permeability Zones

REGENESIS

TANKS BROKEN DOWN AND SOIL ANALYZED



Treatment Solution for Back Diffusion - Tank Study

PlumeStop Technical Bulletin 6.1

REGENESIS

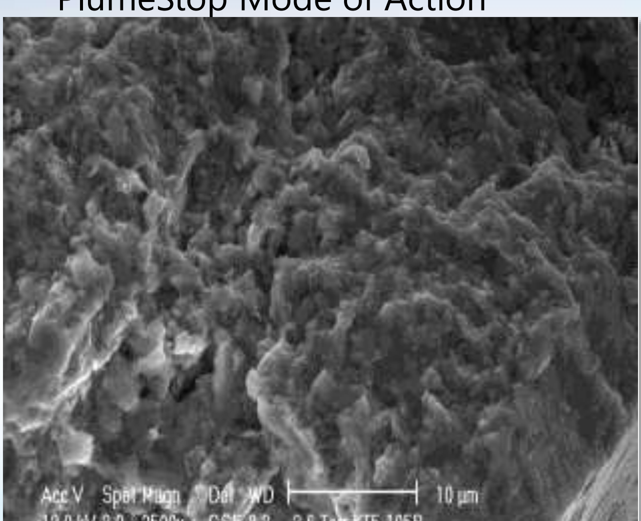
Contaminants Sorbed, Now What?

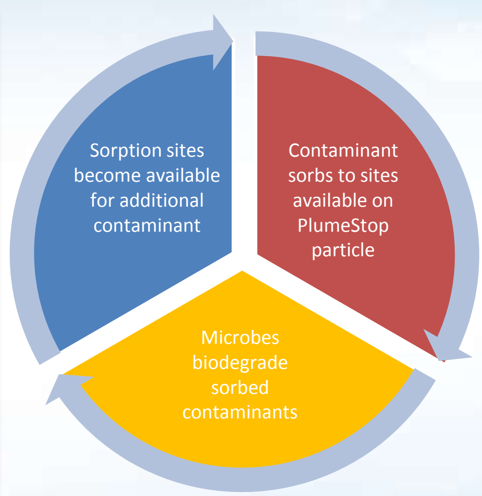
3 Primary Methods of Contaminant Destruction

- **Aerobic Treatment**
  - Electron Acceptor Addition, Sparging…
- **Anaerobic Treatment**
  - Slow release electron donors
  - Lactate, recirculation systems
  - Abiotic: CRS & Plume Stop FE : suspended ZVI
- **Monitored Natural Attenuation/Intrinsic Remediation**

REGENESIS

PlumeStop Mode of Action





REGENESIS

MICROBIAL CHANGES :POST PLUME STOP PILOT MNA SCENARIO

Anaerobic degradation of aromatic hydrocarbons:
76-95% Reduction
Benzene, Chlorobenzene, Xylene

Sulfate				Sulfate Reducers		
	Baseline	4 month	9 months	Baseline	3 months	9 months
	mg/L	mg/L	mg/L	cells/ml	cells/ml	cells/ml
PW01	64	3	<2.5	2111	319000	292000
PW02	31	4.5	<2.5	12900	40600	224000
PW03	74	NA	NA	5170	197	625000
PW04	<5	NA	NA	4140	197	11100
PW05	13	3	<2.5	80900	704000	1190000
PW06	190	<5	<2.5	130000	269000	650000
PW07	<5	2.6J	<2.5	94	143000	315000
PW08	21	6	2.9	11100	11600	315000
PW09	53	2.7J	4.5J	149000	374000	167000
PW10	<5	3.4	10	35200	82000	406000

REGENESIS

Contaminants Treated

- CVOCs, including ethenes, ethanes
- Petroleum hydrocarbons (TPH, BTEX)
- Pesticides
- PFAS

PLUME STOP
Liquid Activated Carbon

REGENESIS

DESIGN VERIFICATION

- What is Design Verification?
  - Pre-application field-verification of remedial design parameters
  - High-resolution identification of COC transport zones
  - Enables accurate placement of reagents for maximum flux-interception

- Why is it necessary?
  - Site investigations typically focus on liability and risk assessment
    - Emphasis on contaminant identification, plume dimensions and migration pathways
  - Design verification focuses on efficient reagent-contaminant contact
    - Emphasis on identification of principal impacted strata, contaminant mass distribution and reagent delivery

REGENESIS

DESIGN VERIFICATION: COMPONENTS

- Continuous Core Logging
  - Recording sedimentology based and geological processes
  - Settling Tube
- COC Lab analysis
- Clear Water Injection

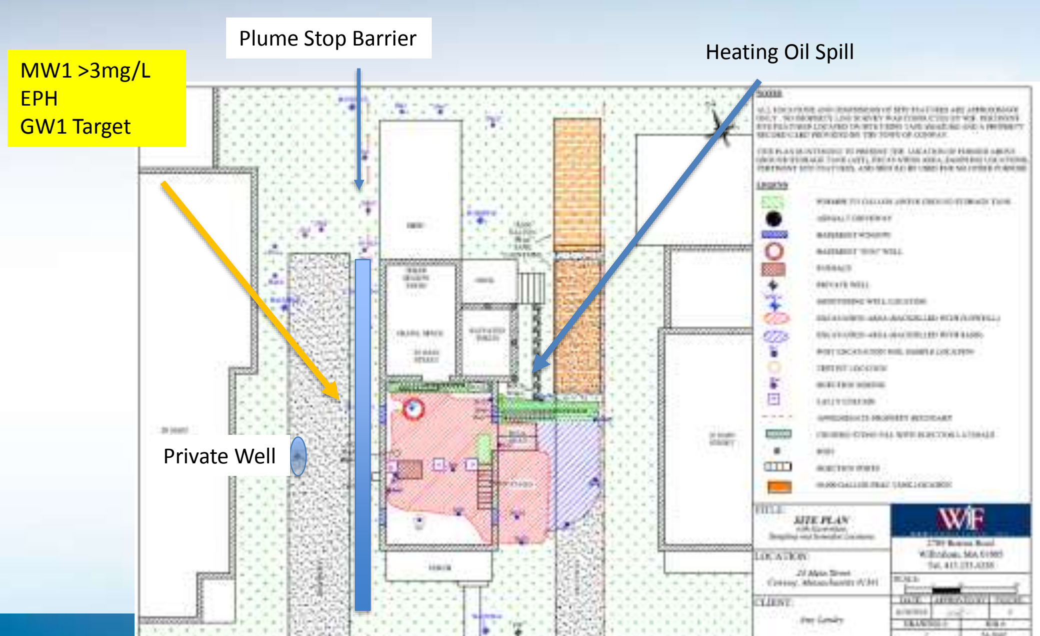
REGENESIS

Combined Remedy

- Heating Oil Property
- Soil and groundwater contamination
- Concern about private well in proximity to spill

- Technologies Used :
- Excavation
- ISCO
- Carbon Sorption/Bioremediation

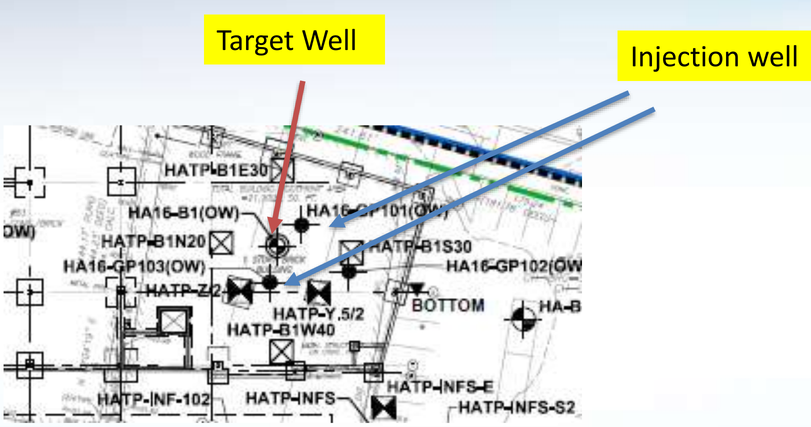
REGENESIS

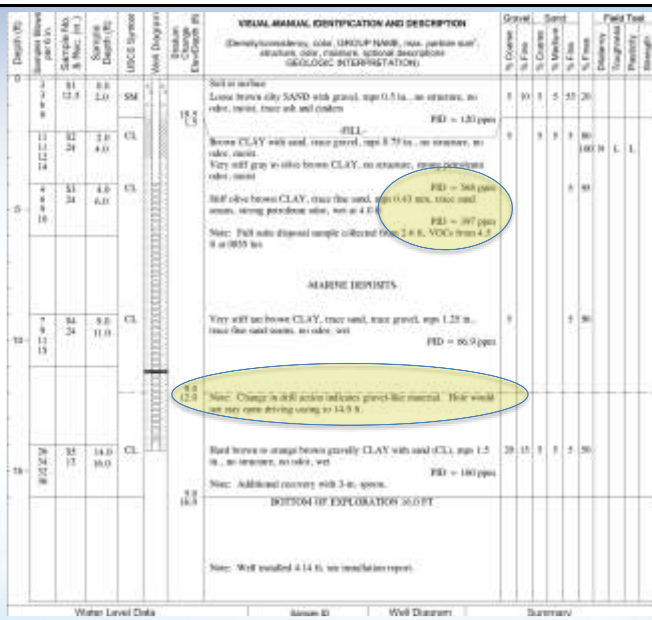


REGENESIS

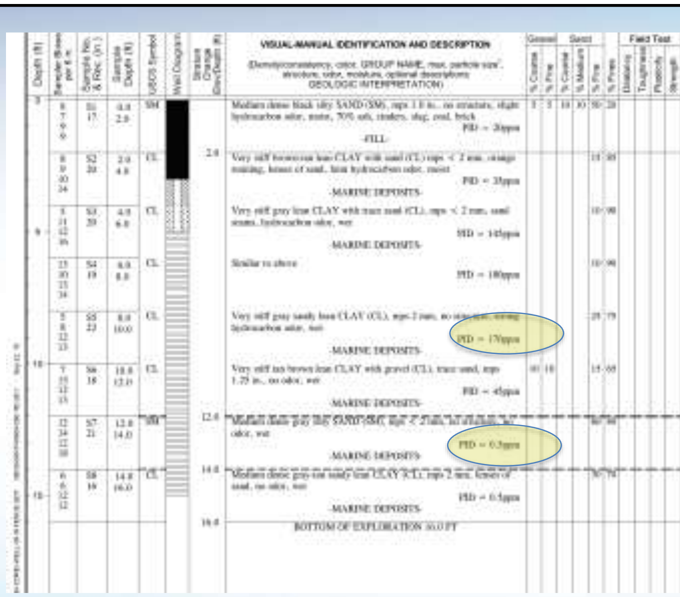
Results

		Total EPH mg/L	Total BTEX mg/L
MW1	baseline	3.36	0.96
	1 month	<0.075 <0.025	<0.005
	2month	<0.075 <0.025	<0.005
	5 month	<0.075 <0.025	<0.005
	12 months	<0.075 <0.025	<0.005




VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION
(Density/consistency, color, GROUP NAME, max. particle size, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)
Gravel
Sand
Field Test
Soil at surface
Loose brown silty SAND with gravel
PID = 1.0 ppm
-FILL-
Brown CLAY with sand, trace gravel
Very stiff gray to olive brown CLAY
Stiff olive brown CLAY, trace fine sand
-MARINE DEPOSITS-
Very stiff tan brown CLAY, trace sand, trace gravel
PID = 66.9 ppm
Note: Change in drill action indicates gravel-like material.
Hard brown to orange brown gravelly CLAY with sand (CL)
PID = 180 ppm
Note: Additional recovery with 3-in. spoon.
BOTTOM OF EXPLORATION 16.0 FT
Water Level Data
Well Diagram
Summary

REGENESIS


VISUAL-MANUAL IDENTIFICATION AND DESCRIPTION
(Density/consistency, color, GROUP NAME, max. particle size, structure, odor, moisture, optional descriptions GEOLOGIC INTERPRETATION)
Gravel
Sand
Field Test
Medium dense black silty SAND (SM)
PID = 20ppm
-FILL-
PID = 35ppm
-MARINE DEPOSITS-
Very stiff gray lean CLAY with trace sand (CL)
-MARINE DEPOSITS-
Similar to above
PID = 180ppm
Very stiff gray sandy lean CLAY (CL)
PID = 170ppm
-MARINE DEPOSITS-
Very stiff tan brown lean CLAY with gravel (CL)
PID = 45ppm
-MARINE DEPOSITS-
Medium dense gray silty SAND (SM)
PID = 0.5ppm
-MARINE DEPOSITS-
PID = 0.5ppm
-MARINE DEPOSITS-
BOTTOM OF EXPLORATION 16.0 FT

REGENESIS

Results

- ISCO: 60% reduction cVOCs
- Plume stop >95% cVOCs
- Formation accepted much less volume than originally designed, however the target zone was impacted and resulted in reduction in target compounds
- DVT activities incorporated with injection well installation

Case Study
- Inner-City Development / Time Pressure -

Downtown Chicago

(skip) (close)

REGENESIS

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

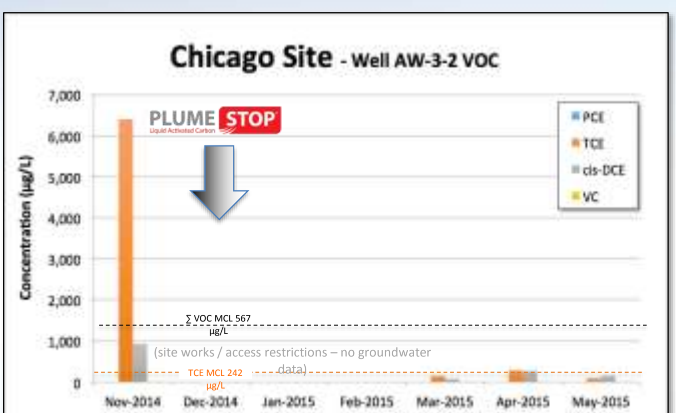
REGENESIS

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)

REGENESIS

Compositional changes consistent with biodegradation

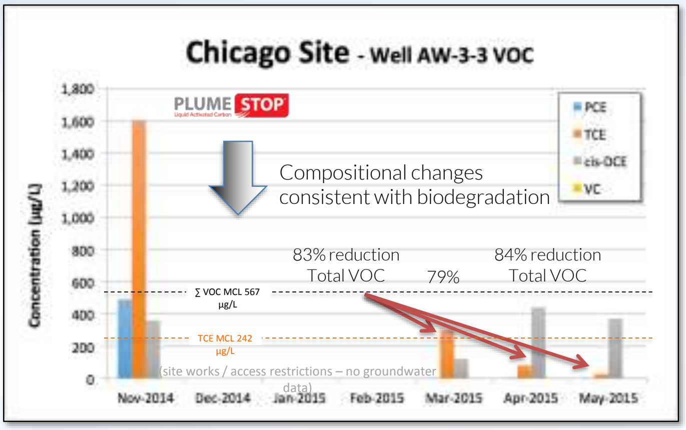


96.9% reduction Total VOC

92.3%

96.5% reduction Total VOC

REGENESIS



REGENESIS

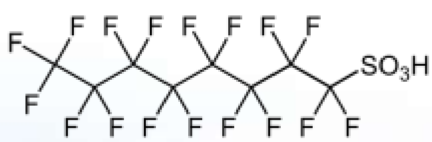
Chicago Site-Status (June 2015)

- 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)
- Targets met – third sampling interval (May 2015)
- Evaluating potential for closure (June 2015)

REGENESIS

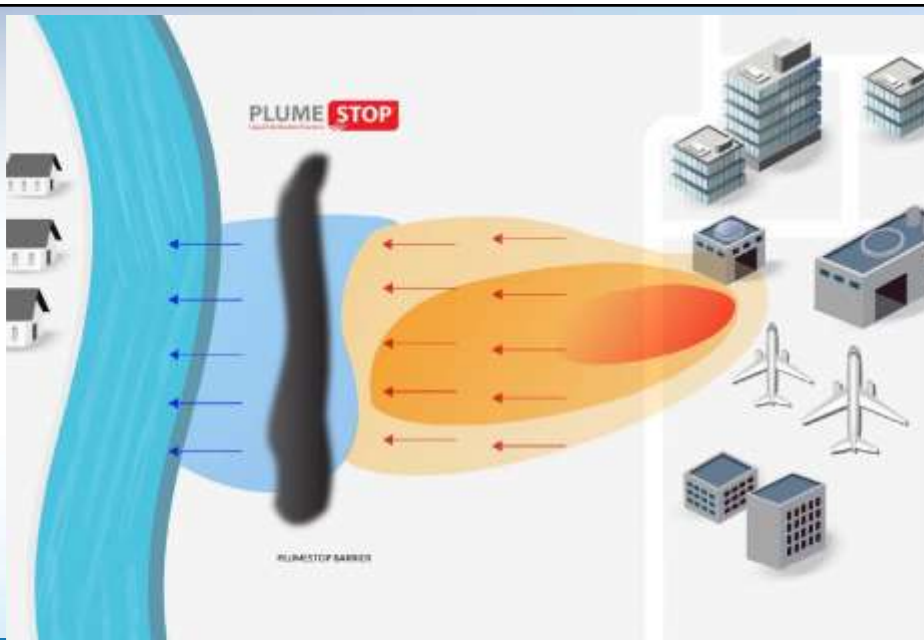
PLUME STOP
Liquid Activated Carbon

- Perfluorinated Compounds -



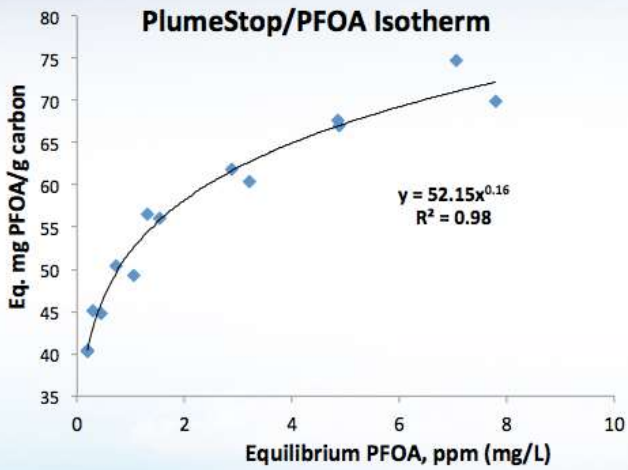
(close)

REGENESIS



REGENESIS

PlumeStop + PFOA/PFOS



	Kf	1/n	PS dose, mg/L: 5 ppm -> .005 ppm
PFOA	52	0.16	224
PFOS	135	0.28	163
PCE	105	0.42	445

Sorption only
(currently no validated destruction methods are available)

REGENESIS

PlumeStop + PFOA/PFOS: Capture Capacity Example

- Plume Concentration 100 µg/L
- Target Concentration 0.5 µg/L
- Seepage velocity 150 ft/year

- PlumeStop barrier width 15' (single application at average dose)

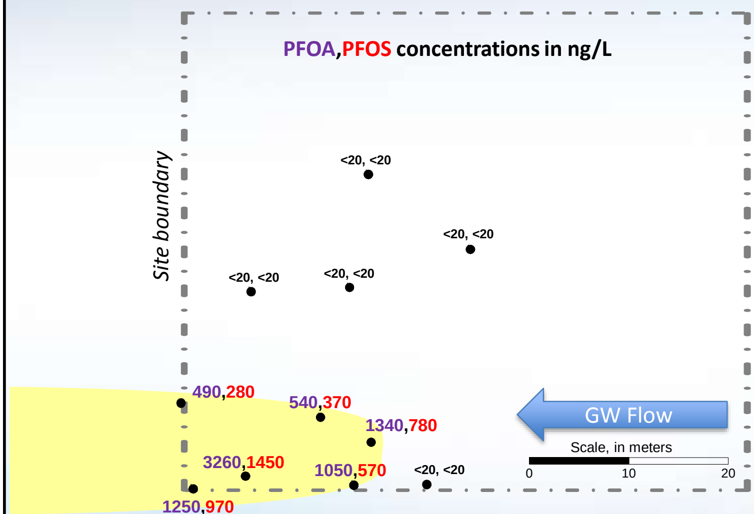
- PFOA = 12 years capture*
- PFOS = 11 years capture*
- PCE = 3 years capture*

More years' capture?
Add another barrier

*based on single component

REGENESIS

Case Study



Location: Canada
Soil: Silty sand
DTW: 4 ft
GW velocity: 2 ft/day
History:

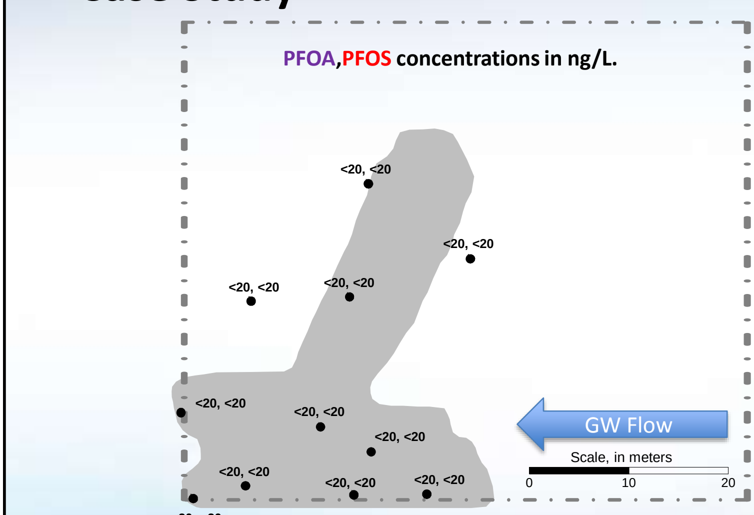
- Hydrocarbon spill
- Former fire training area

Baseline Contamination:
PFOS: 0.3 – 1.5 µg/L
PFOA: 0.5 – 3.3 µg/L

BTEX: <0.5 – 264 µg/L
TPH: <25 – 6,000 µg/L

REGENESIS

Case Study



Remedial Technology Used:

PLUME STOP Liquid Activated Carbon

Results
PFOS: ND (<20 ng/L)
PFOA: ND (<20 ng/L)

BTEX: ND (<0.5 µg/L)
TPH: ND (<25 µg/L)

Through 3, 6, and 15-month (May '17) monitoring events

REGENESIS

Thank You

Maureen Dooley
781 223 5201
mdooley@regenesis.com

REGENESIS