Multi-Site Performance Review of Liquid Activated Carbon for Groundwater Treatment

Chad Northington, PE - Southeast District Manager – Tallahassee, FL

23rd International Petroleum Environmental Conference

November 10, 2016 – New Orleans, LA

REGENESIS

Technology-Based Solutions for the Environment

Outline

- Background
- Technology Development
- Technology Modes of Action
- Applications
- Performance Review

REGENESIS

REGENESIS
REMEDIATION SERVICES

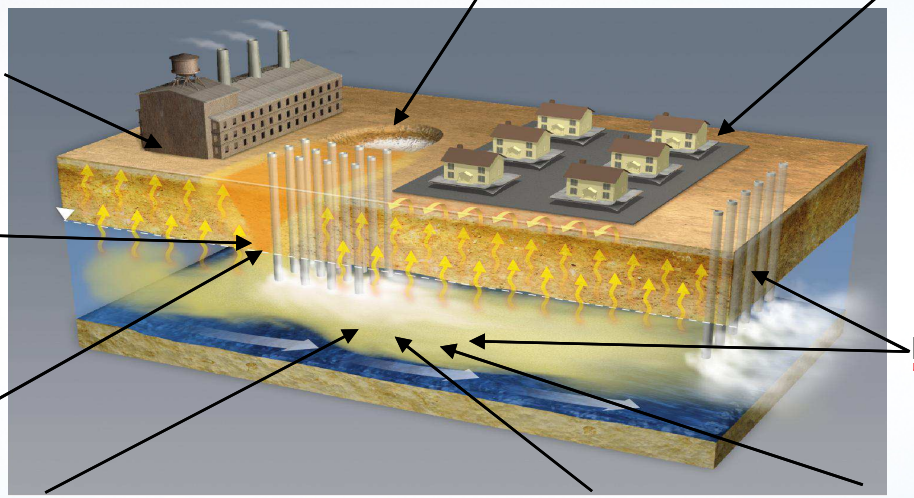
Aerobic Bio — ORC OXYGEN RELEASE COMPOUND

VI-New Construction — Geo-Seal Vapor Intrusion Barrier

VI-Existing Structures — Retro-Coat Vapor Intrusion Coating

Chemical Oxidation — REGEN Ox / PERSULF Ox

Enhanced Desorption — PETRO CLEANZE Enhanced Desorption



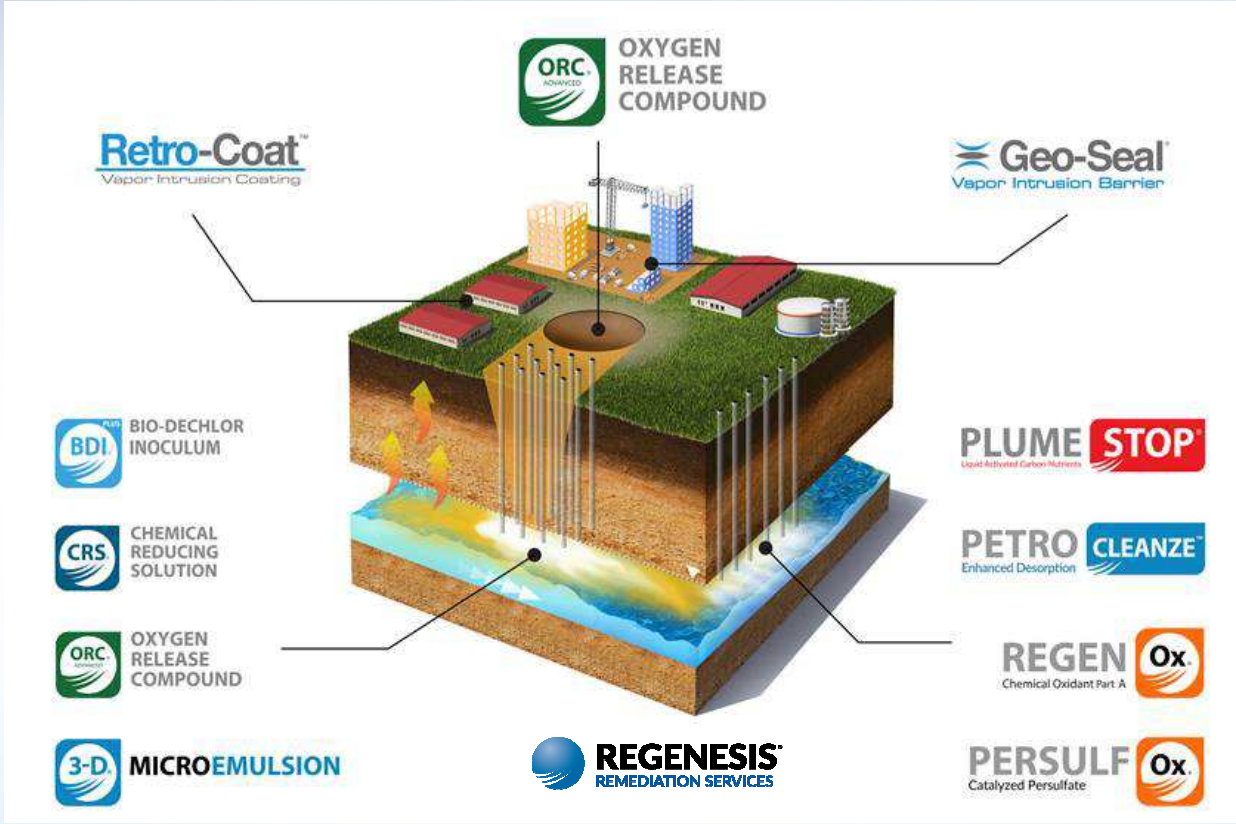
Sorption-Liquid Activated Carbon — PLUME STOP Liquid Activated Carbon

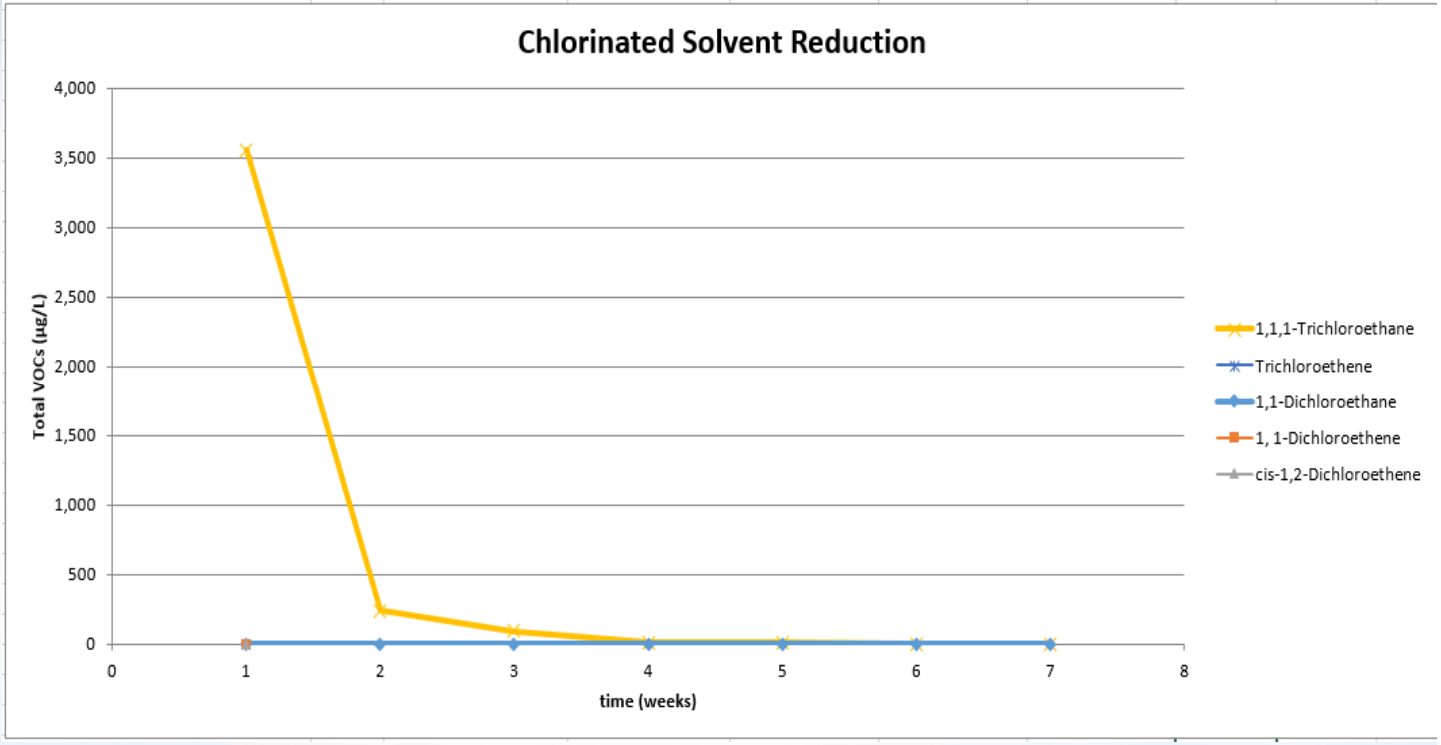
Anaerobic Bio — 3-D MICROEMULSION

BDI BIO-DECHLOR INOCULUM

Aerobic Bio — ORC OXYGEN RELEASE COMPOUND

ISCR — CRS CHEMICAL REDUCING SOLUTION


ORC ADVANCED
OXYGEN RELEASE COMPOUND
Retro-Coat™
Vapor Intrusion Coating
Geo-Seal®
Vapor Intrusion Barrier
BDI PLUS
BIO-DECHLOR INOCULUM
CRS
CHEMICAL REDUCING SOLUTION
ORC ADVANCED
OXYGEN RELEASE COMPOUND
3-D
MICROEMULSION
REGENESIS®
REMEDIATION SERVICES
PLUME STOP®
Liquid Activated Carbon Nutrients
PETRO CLEANZE™
Enhanced Desorption
REGEN Ox
Chemical Oxidant Part A
PERSULF Ox
Catalyzed Persulfate


Chlorinated Solvent Reduction
Total VOCs (µg/L)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
1
2
3
4
5
6
7
8
time (weeks)
1,1,1-Trichloroethane
Trichloroethene
1,1-Dichloroethane
1, 1-Dichloroethene
cis-1,2-Dichloroethene

REGENESIS

PLUME STOP
Liquid Activated Carbon

The Reagent – Timeline

- R&D stages 2007 – 2013
  - Ongoing ancillary research
- Field beta tests 2013 – 2014
  - Early tests still running for long term data
- Commercial launch 2014
  - Battelle Monterey
- Commercial applications from 2014
  - Reviewed in this presentation

REGENESIS

PLUME STOP
Liquid Activated Carbon

Challenge to REGENESIS®

Development of:

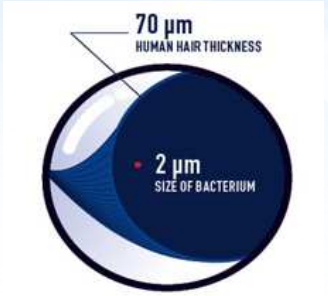
- Flowable and dispersible sorbent
- Stimulates rapid sorption of contaminant
- Permanently biodegrades contaminants

REGENESIS

The Reagent – What it is

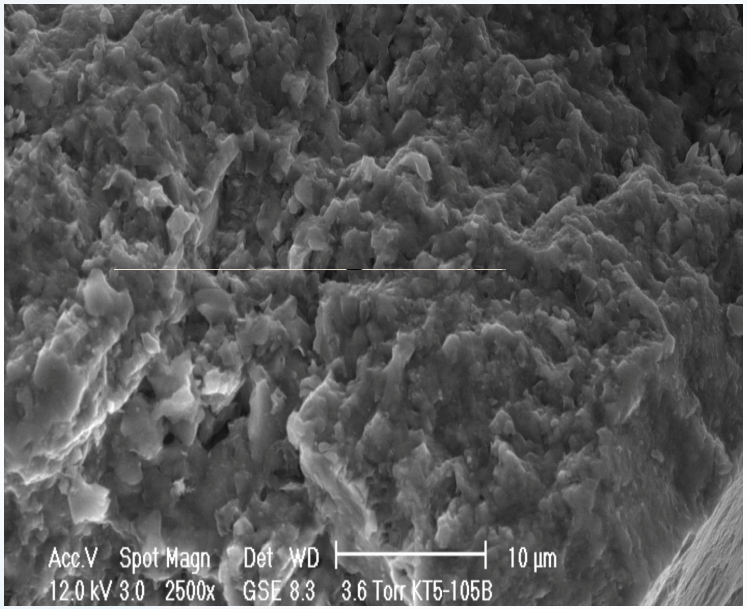
PLUME STOP
Liquid Activated Carbon

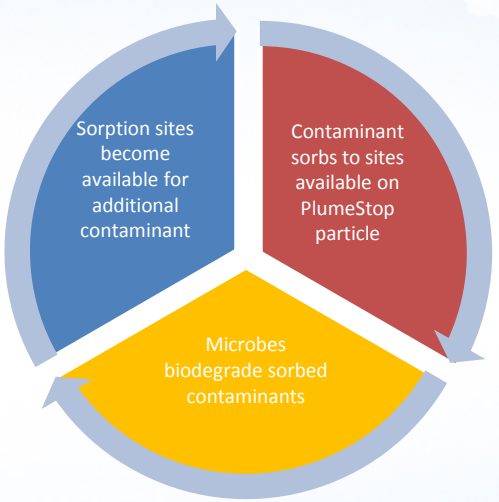
- A highly dispersive, injectable **sorbent** and **microbial growth matrix**
- Colloidal activated carbon (1 – 2 µm)
  - Size of a bacterium – suspends as 'liquid'
  - Huge surface area – extremely fast sorption
- Proprietary anti-clumping / distribution supporting surface treatment
- **Core innovation**
  - Enables wide-area, low-pressure distribution through the soil matrix without clogging



REGENESIS

PlumeStop Mode of Action





REGENESIS

PlumeStop

Powdered Activated Carbon

PLUME STOP
Liquid Activated Carbon

What it Treats

- cVOCs (PCE, TCE, etc.)
- Petroleum Hydrocarbons (TPH, BTEX, PAHs, etc.)
- Oxygenates (MTBE)
- Pesticides/Herbicides
- Energetics
- Emerging Contaminants (PFCs, 1,4-dioxane)

	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**

REGENESIS

Contaminants Sorbed, Now What?

Primary Methods of Contaminant Destruction

- **Aerobic Treatment**
  - Electron Acceptor Addition, Sparging…
- **Anaerobic Treatment**
  - Slow release electron donors
  - Lactate, recirculation systems
- **Enhanced Monitored Natural Attenuation**

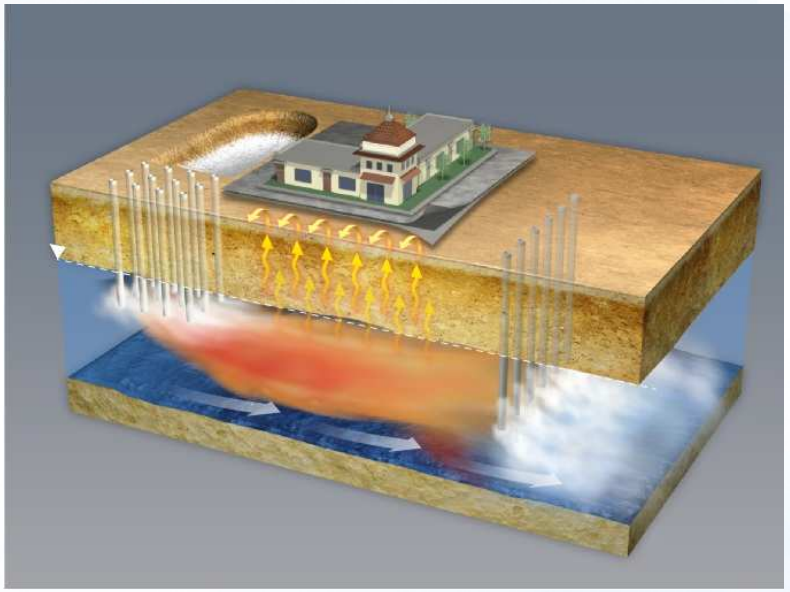
PLUME STOP Liquid Activated Carbon + ORC ADVANCED OXYGEN RELEASE COMPOUND

PLUME STOP Liquid Activated Carbon + HRC HYDROGEN RELEASE COMPOUND

PLUME STOP Liquid Activated Carbon

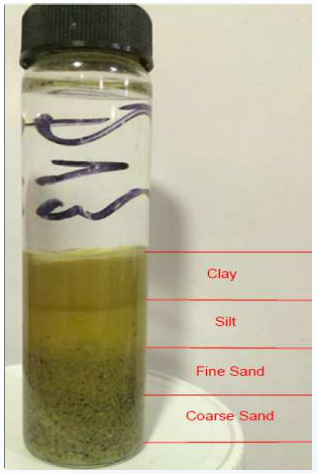
When/Where to Use

1. When time is critical
2. As a long-term barrier
3. To achieve stringent cleanup standards
4. To address matrix back diffusion
5. When remediation is “flat lining”

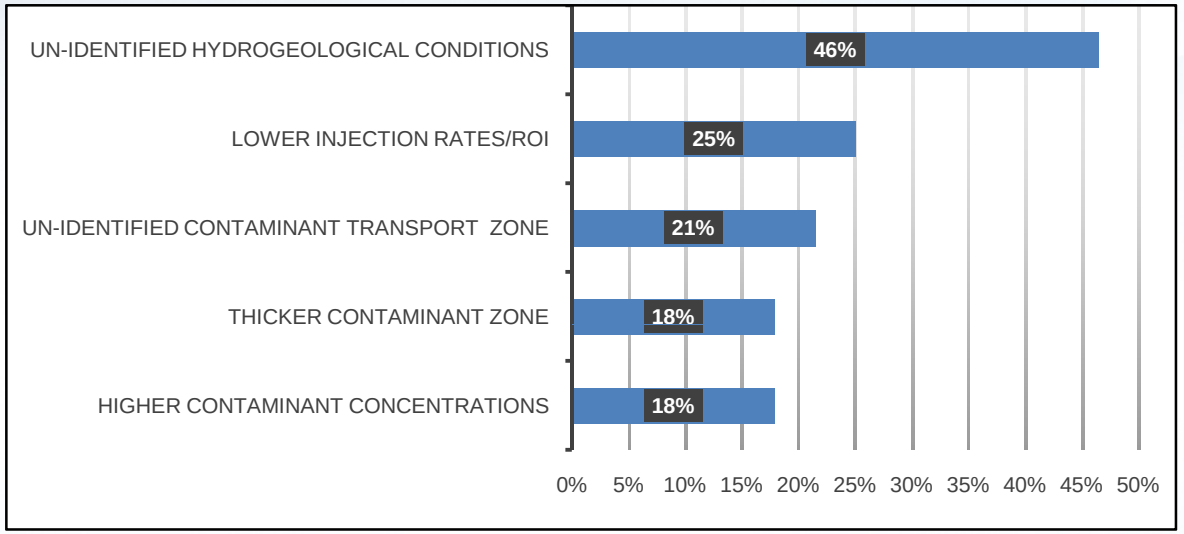


Design Verification Testing (DVT) – REGENESIS PlumeStop® Strategy of Success

- What is DVT?
  - A process of data collection and analysis to verify design assumptions of a site's chemical and geological conditions and the viability of *in situ* injection(s).
- Why is it necessary?
  - Site investigations typically focus on liability and risk assessment
- Focus on efficient reagent-contaminant contact
  - Field-verification of remedial design parameters and delivery rates
  - Identification of contaminant transport strata and distribution
  - Ensure accurate placement of reagents and maximum flux-interception



What is the Outcome?



- 80% of tests to date have found unanticipated results (technical blind spots)
- $^{2}/_{3}$ of preliminary designs have been modified / refined
- 80% of design changes have been cost-neutral

REGENESIS

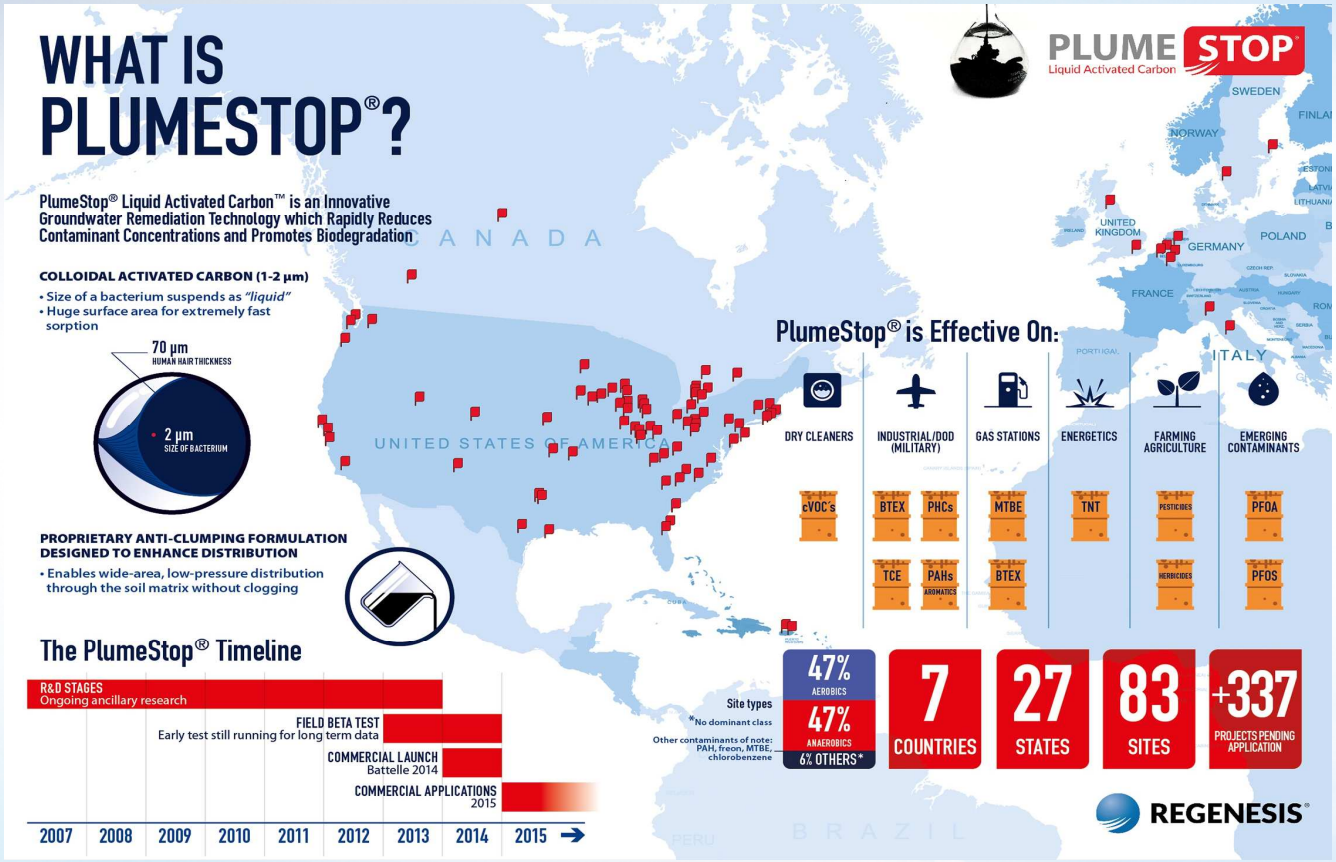
Performance Analytics

REGENESIS

PlumeStop Applications – October 2016

REGENESIS

PlumeStop Applications – October 2016



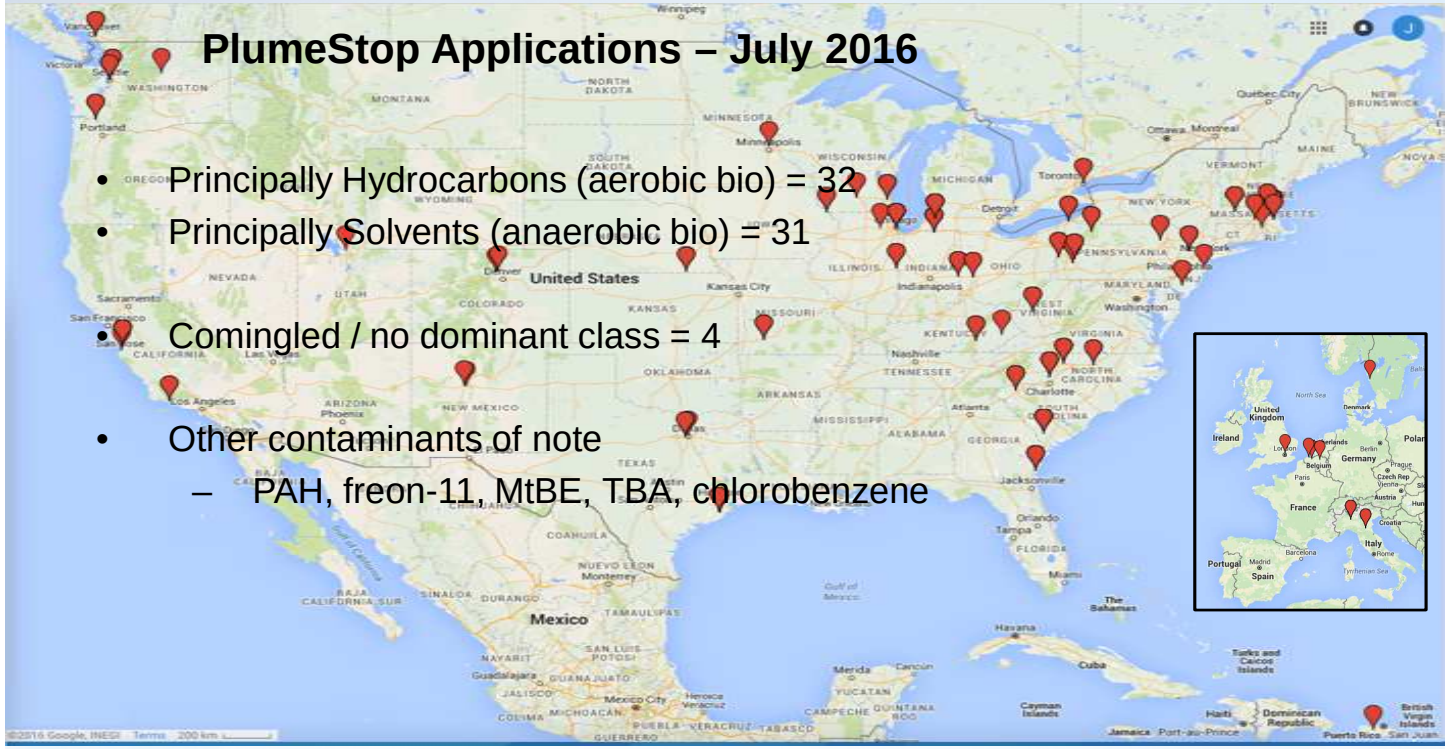
PlumeStop Applications – July 2016

- Number of sites = 67
- Number of states = 24
- Number of countries = 7

- States
  - CA, CO, FL, GA, IA, IL, IN, KY, MA, MI, MO, NC, NE, NJ, NM, OH, PA, PR, SC, TX, UT, WA, WI, WV
- Countries
  - USA, Canada, Italy, Belgium, UK, Sweden, Netherlands
- Scale
  - Pilot 26 (39%)
  - Full 41 (61%)

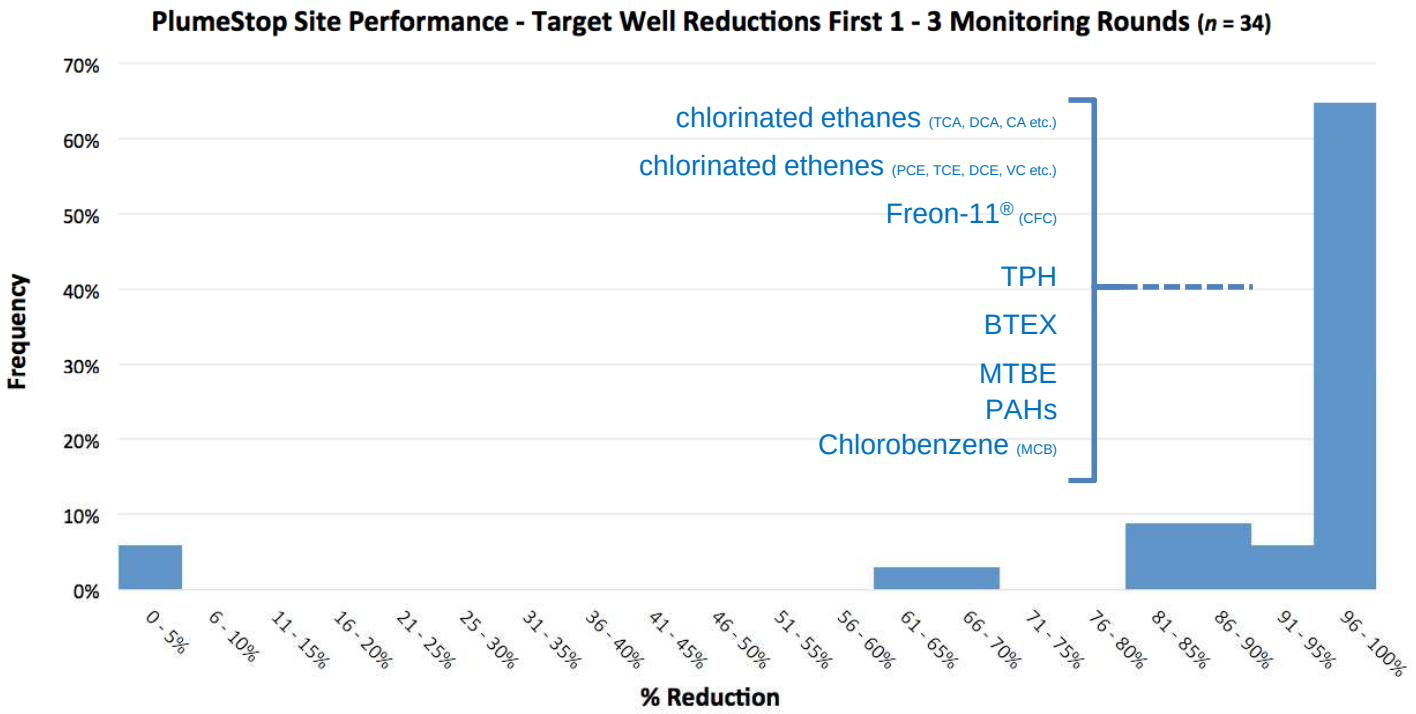
REGENESIS

PlumeStop Applications – July 2016

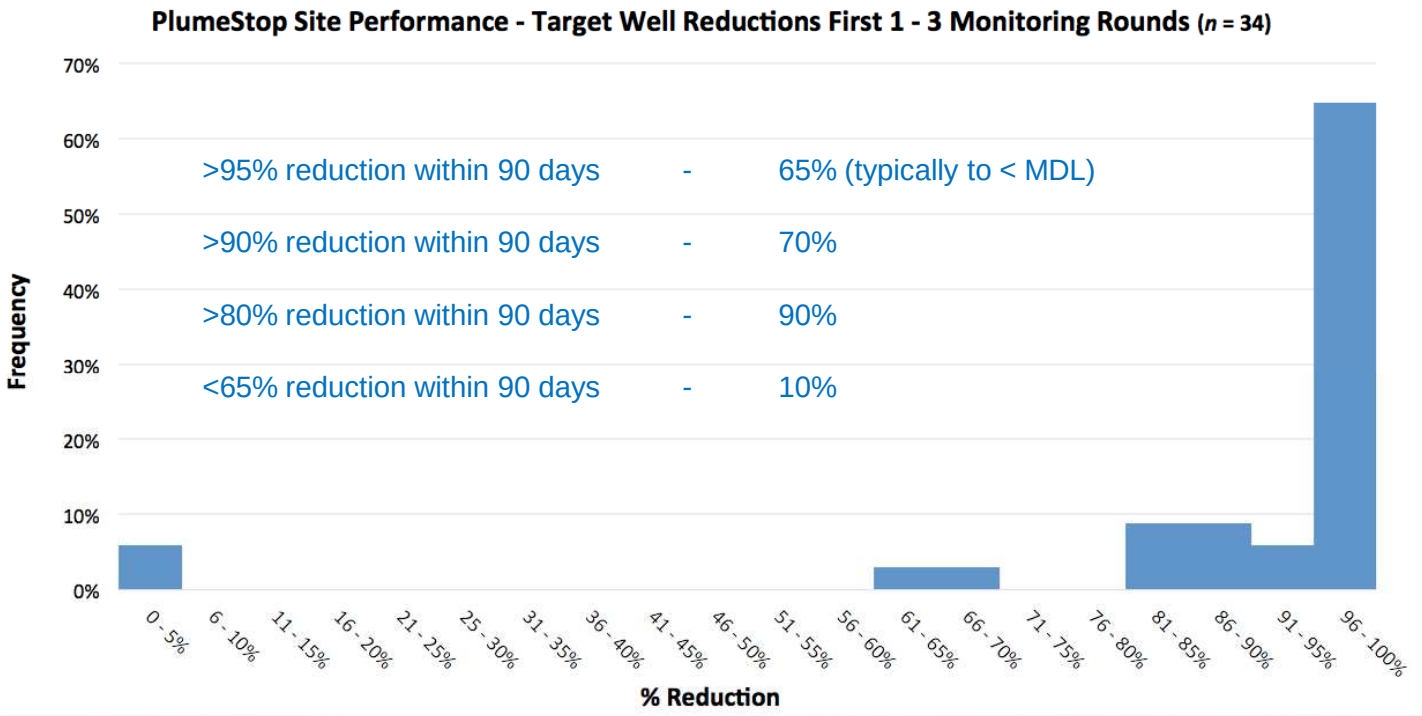


- Principally Hydrocarbons (aerobic bio) = 32
- Principally Solvents (anaerobic bio) = 31
- Comingled / no dominant class = 4
- Other contaminants of note
  - PAH, freon-11, MtBE, TBA, chlorobenzene

REGENESIS


PlumeStop Site Performance - Target Well Reductions First 1 - 3 Monitoring Rounds (n = 34)
Frequency
70%
60%
50%
40%
30%
20%
10%
0%
chlorinated ethanes (TCA, DCA, CA etc.)
chlorinated ethenes (PCE, TCE, DCE, VC etc.)
Freon-11® (CFC)
TPH
BTEX
MTBE
PAHs
Chlorobenzene (MCB)
0 - 5%
6 - 10%
11 - 15%
16 - 20%
21 - 25%
25 - 30%
31 - 35%
36 - 40%
41 - 45%
46 - 50%
51 - 55%
56 - 60%
61 - 65%
66 - 70%
71 - 75%
76 - 80%
81 - 85%
86 - 90%
91 - 95%
96 - 100%
% Reduction

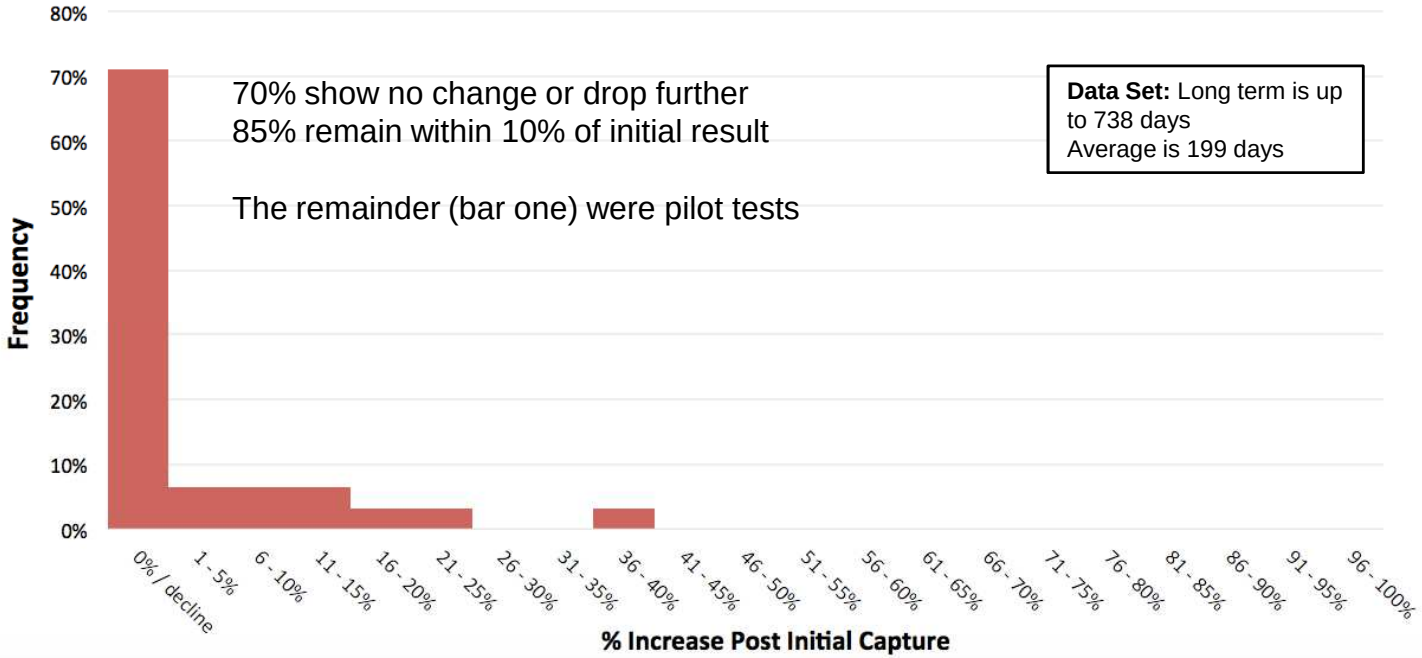
REGENESIS


PlumeStop Site Performance - Target Well Reductions First 1 - 3 Monitoring Rounds (n = 34)
Frequency
70%
60%
50%
40%
30%
20%
10%
0%
>95% reduction within 90 days - 65% (typically to < MDL)
>90% reduction within 90 days - 70%
>80% reduction within 90 days - 90%
<65% reduction within 90 days - 10%
0 - 5%
6 - 10%
11 - 15%
16 - 20%
21 - 25%
25 - 30%
31 - 35%
36 - 40%
41 - 45%
46 - 50%
51 - 55%
56 - 60%
61 - 65%
66 - 70%
71 - 75%
76 - 80%
81 - 85%
86 - 90%
91 - 95%
96 - 100%
% Reduction

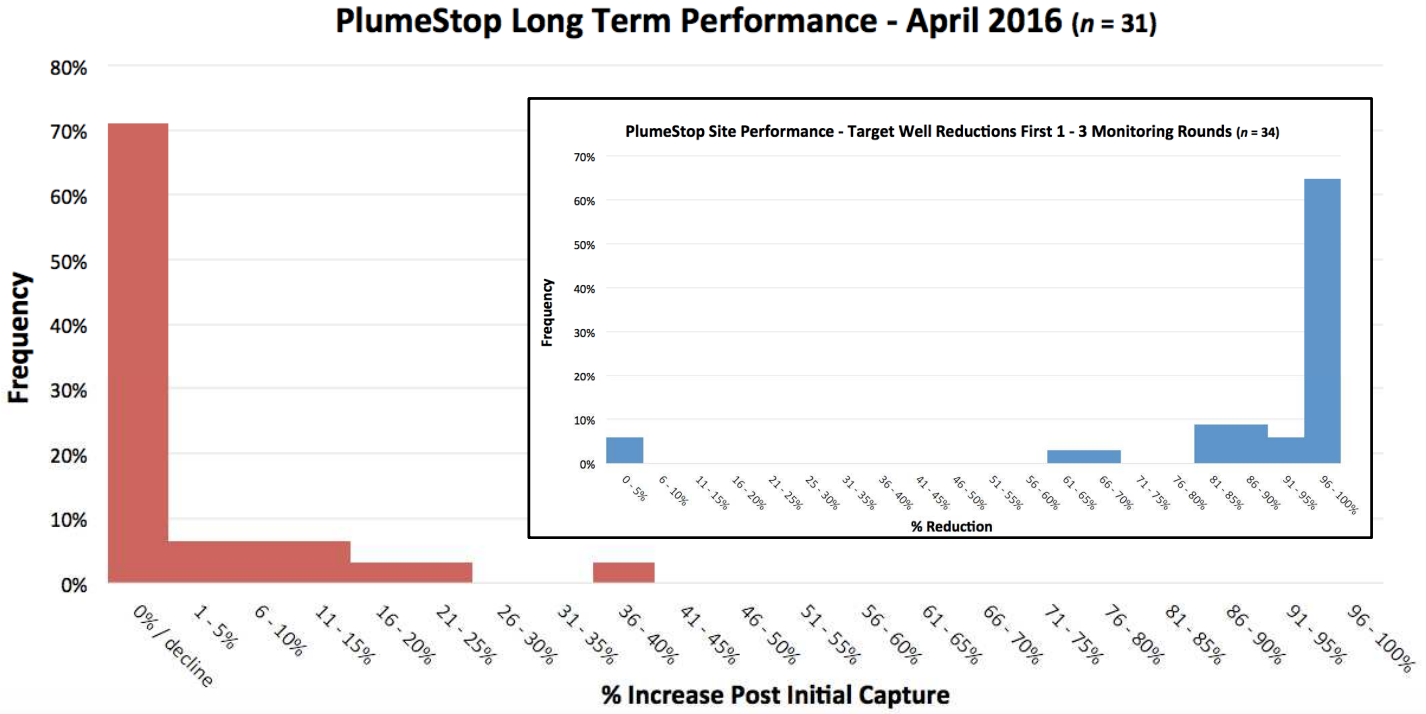
REGENESIS

Stability to Date

PlumeStop Long Term Performance - April 2016 (*n* = 31)



REGENESIS


PlumeStop Long Term Performance - April 2016 (n = 31)
Frequency
80%
70%
60%
50%
40%
30%
20%
10%
0%
0% / decline
1 - 5%
6 - 10%
11 - 15%
16 - 20%
21 - 25%
26 - 30%
31 - 35%
36 - 40%
41 - 45%
46 - 50%
51 - 55%
56 - 60%
61 - 65%
66 - 70%
71 - 75%
76 - 80%
81 - 85%
86 - 90%
91 - 95%
96 - 100%
% Increase Post Initial Capture
PlumeStop Site Performance - Target Well Reductions First 1 - 3 Monitoring Rounds (n = 34)
Frequency
70%
60%
50%
40%
30%
20%
10%
0%
0 - 5%
6 - 10%
11 - 15%
16 - 20%
21 - 25%
25 - 30%
31 - 35%
36 - 40%
41 - 45%
46 - 50%
51 - 55%
56 - 60%
61 - 65%
66 - 70%
71 - 75%
76 - 80%
81 - 85%
86 - 90%
91 - 95%
96 - 100%
% Reduction

Multi-Site Performance Review of Liquid Activated Carbon for Groundwater Treatment

Chad Northington, PE - Southeast District Manager
Tallahassee, Florida
cnorthington@regenesis.com
864-884-4346

REGENESIS
Technology-Based Solutions for the Environment