Eliminating Risk of PFAS in Groundwater

Alana Miller – Northeast District Manager
AGENDA

• PlumeStop – Groundbreaking Technology Development
• Manipulating Retardation Factor and Environmental Risk
• Treatment Strategies
• Case Studies
• Other Services We Provide
COLLOIDAL ACTIVATED CARBON

• Size (1–2 µm)
  • 2-3 OoMs smaller than GAC (500-1,000 µm)
  • Size of a red blood cell
  • Suspended in water
  • Huge surface area
  • Extremely fast sorption
COLLOIDAL ACTIVATED CARBON

• Additives
  • Allow for suspension without clumping
  • Enable wide-area, low-pressure distribution
  • Particles coat the surface of aquifer matrix
  • No impedance of groundwater flow
  • Converts polluted aquifer into purifying filter
PLUMESTOP – REAGENT DISTRIBUTION
PLUMESTOP – REAGENT DISTRIBUTION

Powdered Activated Carbon

PLUMESTOP
Liquid Activated Carbon

500 ml
PLUMESTOP – REAGENT DISTRIBUTION
SEM image of Sand Particles Without PlumeStop
PLUMESTOP - REAGENT DISTRIBUTION

SEM image of sand particles coated with PlumeStop
PLUMESTOP – REAGENT DISTRIBUTION

SEM Image of Sand Particles Coated with PlumeStop
PLUMESTOP LIQUID ACTIVATED CARBON
TYPICAL PERFORMANCE OF PLUMESTOP

- 98% reduction in 1 month
- Minimal CVOC daughter products observed
- Sustained reductions over time
Back Diffusion Management
AQUIFER FLUX ZONES

Higher Permeability Zones
“Freeways”
AQUIFER FLUX ZONES

Lower Permeability Zones
“Parking Lots”
BACK DIFFUSION

Relatively Easy to Remediate Contaminants in the Freeways
IMPACT OF BACK DIFFUSION

- Treatment Initiated
- Contaminant Back Diffusion
- Clean-up standard
PLUMESTOP TREATMENT

Contaminant Mass Back-Diffusing From the Low-Perm Zones is Captured
PLUME STOP INJECTION
PLUMESTOP ELIMINATES BACK-DIFFUSION IMPACT
PASSIVE MANAGEMENT OF GROUNDWATER PLUMES LONG-TERM
WHICH BRINGS US TO...

Perfluorinated Compounds
**PLUMESTOP + PFOA/PFOS**

**PlumeStop/PFOA Isotherm**

\[
y = 52.15x^{0.16} \\
R^2 = 0.98
\]

<table>
<thead>
<tr>
<th>Compound</th>
<th>Kf</th>
<th>1/n</th>
<th>PS dose, mg/L: 5 ppm -&gt; 0.005 ppm</th>
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</thead>
<tbody>
<tr>
<td>PFOA</td>
<td>52</td>
<td>0.16</td>
<td>224</td>
</tr>
<tr>
<td>PFOS</td>
<td>135</td>
<td>0.28</td>
<td>163</td>
</tr>
<tr>
<td>PCE</td>
<td>105</td>
<td>0.42</td>
<td>445</td>
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</table>

*Sorption only*  
*(currently no validated destruction methods are available)*
PLUMESTOP + PFOA/PFOS: CAPTURE EFFICIENCY

So what happens over time?

• Won’t the barrier eventually fill up and breakthrough?

• As PFAS do not degrade, the answer is yes

• What’s important is how long this will take
PLUMESTOP + PFAS: RETARDATION FACTOR

For a PlumeStop Barrier at a Mid-Range Dose:

PFOA
- The R of a 1,000 µg/L plume is 80
- The R of a 100 µg/L plume is 570
- The R of a 10 µg/L plume is 4,000

PFOS
- The R of a 1,000 µg/L plume is 375
- The R of a 100 µg/L plume is 2,000
- The R of a 10 µg/L plume is 10,000

*based on individual components
PLUMESTOP + PFAS: RETARDATION FACTOR

Example:
• PlumeStop barrier width 16’ (single application at mid-range dose)
• 160’ per year seepage velocity
• 100 µg/L influent concentration

• Groundwater transit time 36.5 days
• PFOA transit time* = 20,800 days (57 years)
• PFOS transit time* = 73,000 days (200 years)

* transit time peak based on individual components

This is at 100 µg/L
At lower influent concentrations, the retardation quickly becomes much greater.
ELIMINATE THE RISK FROM PFAS

Environmental RISK = (PFAS) X (Exposure)
ELIMINATE THE RISK FROM PFAS

• “Risk-Based Corrective Action” is commonplace throughout world since 1990’s

• “No Further Action” granted if plume not expanding and no receptor impacted (water well or surface water)
STRATEGY #1 – SIMPLE PLUME CUT-OFF BARRIER

Description
– Single barrier of PlumeStop®
– Limits plume expansion

Application
– Protection of property boundary
  • (entering site or exiting site)
– Protection of receptor (shown)
  • (e.g. water body; well)
– Plume minimization
  • Liability containment
  • (possible) regulatory compliance
STRATEGY #2 – SEQUENCE OF BARRIERS

Description
– Multiple barriers of PlumeStop®
– Progressive elimination of plume

Application
– Addresses entire plume
– Utilizes advection for efficiency
– Particularly suited for:
  – Large plumes (compare cost of grid injection)
  – Built-up areas / restricted access
    – Barriers in access corridors / roadways
STRATEGY #3 – POTENTIAL SOURCE CONTAINMENT

Description
- Pre-emptive source control
- PlumeStop® *in situ* ‘berm’

Application
- Ring-fence known *potential* source
- Avoidance of plume generation
- Provide extra time for emergency response
STRATEGY #4 – LOCALIZED RECEPTOR PROTECTION

Description
- Individual receptor protection
- ‘Brita®’ filter in-ground

Application
- Protection of abstraction wells
  • (e.g. agricultural)
- Interim measure where plume is large
- Amenable to push-pull application
  • Fast response
  • Minimally intrusive
  • Eliminates requirement for additional borings
  • Ability to treat deep wells
CASE STUDY
PFAS – FORMER FURNITURE FACILITY
ONTARIO, CANADA

INSITU
BACKGROUND

Initial Driver: Hydrocarbons
- Mixed chain lengths, 100 – 5,000 µg/L

Formation
- Silty sand – till based with sand seams
- Water at 3 – 5’ below grade

Former Fire Training Area
- History of furniture manufacturing
- PFAS tested for just in case and found!
EXTENT OF PFAS AND PFOA CONTAMINATION PRE-TREATMENT
PFAS FORMER FURNITURE SITE

Site Location: Ontario, Canada

Canada PFAS Site

- Hydrocarbons to n/d
- PFAS to n/d
- Two years and counting...

Concentration (ng/L)

MW1  MW2  MW4  MW5  MW8  MW11

PFOS Pre  PFOA Pre  PFOS Post  PFOA Post
INDEPENDENT RESEARCH AND CALIBRATION ONGOING

• Involved in independent PFAS research

• Modeled contaminant hydrogeology at project site

• Performed sensitivity analysis under a range of $K_f$ values to estimate the longevity of capture
Long Term Results

- Modeled (Grant Carey, PhD)
  - Conservative Analytical Solution
    - Mass flux 161 ug/m²/day
    - Source half life 30 years
  - Source Zone PFOA
    - Strongly adsorbed
    - ~100 years $1 \times 10^{-6}$ ng/L
  - Source Zone PFOS
    - Not as strongly adsorbed
    - ~100 years ~24 ng/L
COST COMPARISON

Actual Cost of PlumeStop Treatment
• Design, product and application (total) $73,000
• Ongoing system O & M (ex. monitoring) $0

$73,000

Estimated Cost of Pumping & Treating (Most Efficient GAC)
• Design, permitting, construction, startup $150,000
• Ongoing system O&M $1,200,000
  • (ex. monitoring @ $60k/yr X 20 yrs)

$1,350,000
Case Published:

REMEDIATION Journal
Volume 28, No. 2
Summer 2018
Wiley Press
CASE STUDY
PFAS – SOLVENT RECOVERY FACILITY
CONNECTICUT

de maximis, inc. GEI Consultants
Solvent Recovery Services of New England Superfund Site in CT

- Plume Stop and Aqua ZVI Application to address cVOC and PFAS contamination
- Target combined 5 compounds 70 ppt: PFOA, PFOS, PFNA, PFHxS, PFHpA
- Starting concentration: max 148ppt
- Applied Reagents in Trench and laterals
- Application July 23-25, 2018
- Aqua ZVI: 4,000 lbs
  Plume Stop: 21,600 lbs
Solvent Recovery Services of New England Superfund Site in CT

- 8,800 lbs of PlumeStop and 4,000 lbs of ZVI into the upgradient trench
- 12,800 lbs of PlumeStop into the downgradient trench (including four 50’ distribution trenches)
Results from PMP-1 (within trench)

Σ5CT is sum of 5 PFAS compounds (PFOA, PFOS, PFNA, PFHpA, and PFHxS)
Results from EMW-1S (10 ft downgradient of trench)

Σ5CT is sum of 5 PFAS compounds (PFOA, PFOS, PFNA, PFHpA, and PFHxS)
Results from EMW-4S (about 50 ft downgradient of trench)

∑5CT is sum of 5 PFAS compounds (PFOA, PFOS, PFNA, PFHpA, and PFHxS)
Should we expect GAC and PlumeStop to work the same?

What about the shorter chain PFAS species, will they adsorb to PlumeStop?

- Lab studies
- Bench test with groundwater from an Italian site
ACTIVATED CARBON PARTICLE SIZE AND ADSORPTION EFFICACY

- Recent study demonstrated 2 OoM improved removal with smaller activated carbon particles
  - 180–500 mm AC removed 90% PFOS
  - <53 mm AC removed 99.9+% PFOS

- *GAC particles are less efficient at adsorbing PFAS than PlumeStop because of their size

PFAS ADSORPTION KINETICS & PARTICLE SIZE

• The reason can be attributed to kinetics: intraparticle diffusion

• Smaller particles provide better access to all the sorption sites that activated carbon provides.

Should we expect GAC and PlumeStop to work the same?

What about the shorter chain PFAS species, will they adsorb to PlumeStop?

• Lab studies
• Bench test with groundwater from an Italian site
<table>
<thead>
<tr>
<th>Analyte</th>
<th>Units</th>
<th>Baseline 1</th>
<th>Baseline 2</th>
<th>Control 1</th>
<th>Control 2</th>
<th>Treated 1</th>
<th>Treated 2</th>
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<tbody>
<tr>
<td>4:2 fluorotelomersulfonate</td>
<td>ng/l</td>
<td>210</td>
<td>230</td>
<td>280</td>
<td>260</td>
<td>&lt; 0.96</td>
<td>&lt; 0.95</td>
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<tr>
<td>6:2 fluorotelomersulfonate</td>
<td>ng/l</td>
<td>6,900</td>
<td>7,600</td>
<td>7,800</td>
<td>7,800</td>
<td>&lt; 2.9</td>
<td>&lt; 2.9</td>
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<td>8:2 fluorotelomersulfonate</td>
<td>ng/l</td>
<td>200</td>
<td>190</td>
<td>240</td>
<td>210</td>
<td>&lt; 1.9</td>
<td>&lt; 1.9</td>
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<tr>
<td>Perfluoro-octanesulfonate</td>
<td>ng/l</td>
<td>8,300</td>
<td>8,300</td>
<td>9,300</td>
<td>8,700</td>
<td>&lt; 0.39</td>
<td>&lt; 0.38</td>
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<tr>
<td>Perfluorobutanesulfonate</td>
<td>ng/l</td>
<td>78</td>
<td>75</td>
<td>89</td>
<td>85</td>
<td>&lt; 0.29</td>
<td>&lt; 0.29</td>
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<tr>
<td>Perfluorobutanoic acid</td>
<td>ng/l</td>
<td>920</td>
<td>930</td>
<td>950</td>
<td>880</td>
<td>34</td>
<td>34</td>
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<td>Perfluorodecanoic acid</td>
<td>ng/l</td>
<td>&lt; 10</td>
<td>&lt; 9</td>
<td>9.4</td>
<td>&lt; 8.8</td>
<td>&lt; 0.96</td>
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<tr>
<td>Perfluoroheptanesulfonate</td>
<td>ng/l</td>
<td>94</td>
<td>99</td>
<td>93</td>
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<td>&lt; 0.38</td>
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<tr>
<td>Perfluoroheptanoic acid</td>
<td>ng/l</td>
<td>1,200</td>
<td>1,200</td>
<td>1,500</td>
<td>1,300</td>
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<td>&lt; 0.29</td>
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<tr>
<td>Perfluorohexanesulfonate</td>
<td>ng/l</td>
<td>1,700</td>
<td>1,800</td>
<td>2,000</td>
<td>2,100</td>
<td>&lt; 0.39</td>
<td>&lt; 0.38</td>
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<tr>
<td>Perfluorohexanoic acid</td>
<td>ng/l</td>
<td>4,500</td>
<td>4,600</td>
<td>5,200</td>
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<td>&lt; 0.38</td>
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<tr>
<td>Perfluorononanoic acid</td>
<td>ng/l</td>
<td>570</td>
<td>590</td>
<td>610</td>
<td>620</td>
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<tr>
<td>Perfluorooccanoic acid</td>
<td>ng/l</td>
<td>990</td>
<td>1,000</td>
<td>1,100</td>
<td>1,100</td>
<td>&lt; 0.29</td>
<td>&lt; 0.29</td>
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<tr>
<td>Perfluoropentanesulfonate</td>
<td>ng/l</td>
<td>110</td>
<td>100</td>
<td>110</td>
<td>110</td>
<td>&lt; 0.39</td>
<td>&lt; 0.38</td>
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<tr>
<td>Perfluoropentanoic acid</td>
<td>ng/l</td>
<td>7,800</td>
<td>7,700</td>
<td>9,000</td>
<td>8,000</td>
<td>&lt; 1.9</td>
<td>&lt; 1.9</td>
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<tr>
<td>Perfluoroundecanoic acid</td>
<td>ng/l</td>
<td>5</td>
<td>5</td>
<td>4.8</td>
<td>3.9</td>
<td>&lt; 0.39</td>
<td>&lt; 0.38</td>
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<tr>
<td><strong>Total PFAS</strong></td>
<td></td>
<td><strong>33,577</strong></td>
<td><strong>34,419</strong></td>
<td><strong>38,286</strong></td>
<td><strong>36,263</strong></td>
<td><strong>34</strong></td>
<td><strong>34</strong></td>
</tr>
</tbody>
</table>
SUMMARY

• PlumeStop is a Proven Technology
  • Treatment of CVOCS, Petroleum Hydrocarbons, and PFAS

• Eliminates the RISK of PFAS in groundwater

• Passive Plume Management

• Cost Effective!
  • Low Cap-Ex
  • Low Op-Ex
PETROFIX REMEDIATION FLUID
COMPOSITION

- Fluid, 400 lbs: 32% activated carbon + slow-release sulfate
  - No transport polymers
- EA Blend, 20 lbs: nitrate/sulfate mix or sulfate salts only
  - Tech bulletin explaining PetroFix treatment approach
PETROFIX DESIGN ASSISTANT

Design Assistant Lets You:
• Track Your Orders
• Manage Your Sites
• Recommends Designs
• Access Helpful Resources
• Archive Your Sites
Research & Development

Remediation Technologies

Land Science Technologies (VI)

Remediation Services

REMEDIATION TECHNOLOGY CLASSES:

• Enhanced Aerobic Biodegradation
  • ORC-Advanced

• Enhanced Anaerobic Biodegradation
  • 3-D Microemulsion

• In Situ Chemical Oxidation (ISCO)
  • RegenOx
  • PersulfOx

• In Situ Chemical Reduction (ISCR)
  • Chemical Reducing Solution
  • AquaZVI
  • MicroZVI

• Bioaugmentation
  • BDI Plus

• In Situ Sorption and Biodegradation
  • PlumeStop
  • PetroFix

• Metals Immobilization
  • Metals Remediation Compounds (MRC)
REMEDIAL APPROACHES OFFERED:

DIRECT PUSH INJECTION
- In-Situ Chemical Oxidation (ISCO)
- In-Situ Chemical Reduction (ISCR)
- Bioaugmentation
- In Situ Sorption & Biodegradation
- Enhanced Aerobic Bioremediation
- Enhanced Anaerobic Bioremediation

HORIZONTAL DRILL:
- ISCO
- ISCR
- Bioaugmentation
- In Situ Sorption & Biodegradation
- Enhanced Aerobic Bioremediation
- Enhanced Anaerobic Bioremediation

WELLS
- ISCO
- ISCR
- Sorption
- Enhanced Anaerobic Bioremediation

EXCAVATION
- Soil Mixing & Handling
Three core Technologies
federal and state regulatory approved

Geo-Seal®
Vapor Intrusion Barrier

Vapor-Vent™
Vapor Collection System

Retro-Coat™
Vapor Intrusion Coating
Thank You!

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