In Situ Remediation with Colloidal Activated Carbon to Reduce PFAS Risk

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Vice President, West Region

Wednesday, March 19, 2025

AEHS Foundation

AEHS West 2025
34th Annual International Conference
on Soil, Water, Energy, and Air

March 17-20, 2025

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Presentation Overview

- 30+ years of REGENESIS
- PFAS challenges
- Misconceptions with conventional approaches (P&T) for PFAS
- Risk perspective on *in situ* PFAS remediation
- Colloidal Activated Carbon
  - Efficacy, cost, and case studies

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Corporate Overview

Technologies Offered

Enhanced Aerobic Biodegradation

Enhanced Anaerobic Biodegradation

In Situ Chemical Oxidation (ISCO)

In Situ Chemical Reduction (ISCR)

Bioaugmentation

Metals Immobilization

In Situ Sorption and Biodegradation

About REGENESIS

REGENESIS

We develop cutting-edge solutions to remediate soil and groundwater in situ.

Research and Development

Remediation Technologies

Remediation Services

Land Science Technologies (VI)

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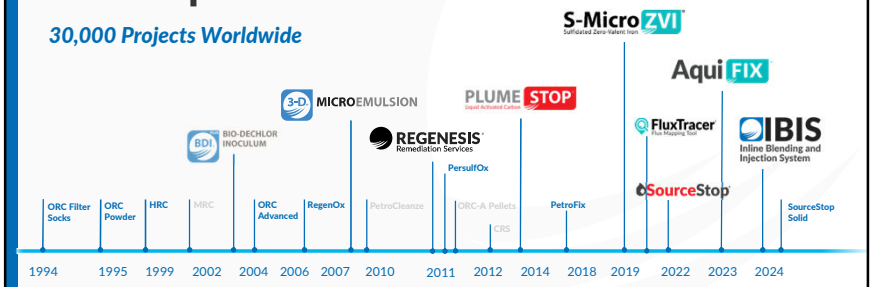
30 Years of Continuous Development

30,000 Projects Worldwide



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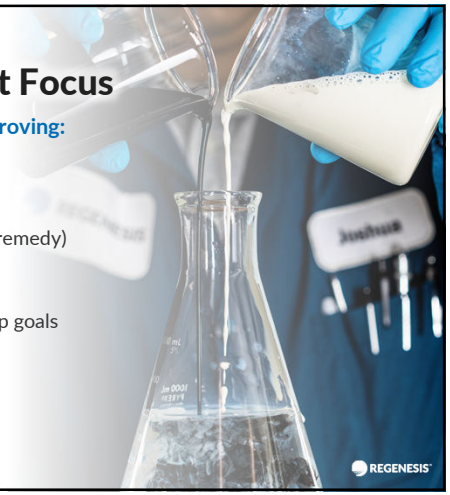
Colloidal Development Focus



Overcoming in situ challenges by improving:

- Distribution (contact)
- Reactivity (speed)
- Persistence (longevity)
- Compatibility (co-apply, combined remedy)

With the goal of:

- Single application to achieve cleanup goals
- Achieve cleanup goals sooner
- Reduce total project cost

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What is a Colloidal Technology?

A homogeneous mixture of micron-sized particles dispersed in a liquid

- **PlumeStop (left image) is a 1-2 micron (the size of a red blood cell) activated carbon colloid that is dispersed in water and does not settle.**

Stabilized Micro-Scale AC (Colloidal)

De-Stabilized Micro-Scale AC (Non-Colloidal)

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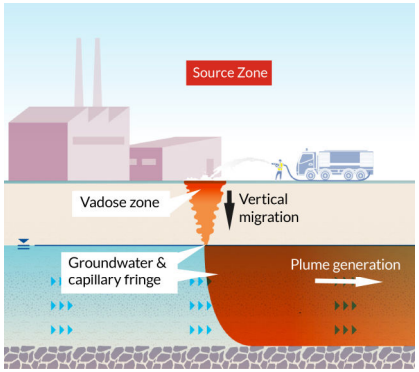
PFAS Challenges

- PFAS are Resistant to Degradation (forever chemicals)[1]
- Found Everywhere[2,3]
- PFAS Fate & Transport is Complex[1]
- Lowest Cleanup Criteria of any COCs we Traditionally Manage[4]
  - US EPA MCLs April 2024



1. ITRC PFAS
2. Ian Cousins, et. al., 2022 Environmental Science & Technology
3. D. Andrews et. al., 2023 Science of the Total Environment
4. USEPA PFAS MCLs, April 2024

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What is your Experience with PFAS?

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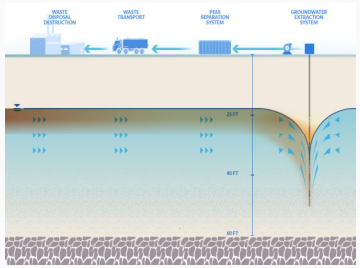
Two Available Approaches:

Pump & Treat
Contain plume with pumping



In Situ Remediation
Immobilize the PFAS within the aquifer

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Will P&T Flush Aquifers of Contaminants?

- After decades, P&T has shown to be ineffective in achieving low ppb goals for VOCs such as TCE[1,2,3,4,5]
- Key PFAS (e.g. PFOS) sorb 25X more strongly to aquifer matrix [6,7]
- New regulatory standards are 1000X lower for PFOS at 4.0 ppt[8]!

It will likely take 100s of years of pumping to flush the hazard of PFAS!

1. D. Mackay and J. Cherry, Environ. Sci. Technol. 1989, 23, 6, 630-636.
2. US Government Accounting Office, 2005, GAO-05-666
3. National Research Council, 1994. Alternatives for groundwater cleanup.
4. S. Chapman and B. Parker, 2005, *Water Resources Research*, 41, 12.
5. Guo,Z. Brusseau, M.L. & Fogg, G. E., 2019, *Journal of Hazardous Materials*, 365,796-803
6. USEPA, 1996, Soil Screening Guidance: Technical Background Document
7. ITRC, 2023. PFAS Technical and Regulatory Document
8. USEPA, 2024, PFAS MCL SDA

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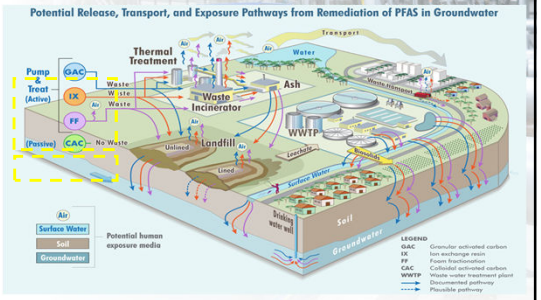
Will P&T Actually Increase the Risk of PFAS Exposure and Spread CERCLA Liability?

- Generates a PFAS waste
- Waste handling increases PFAS risk to human health and the environment [1]
- Spreads CERCLA Liability throughout the waste chain…..FOREVER[2]



1. L. Hall, et. al, 2024, Remediation Journal
2. USEPA. Superfund Liability

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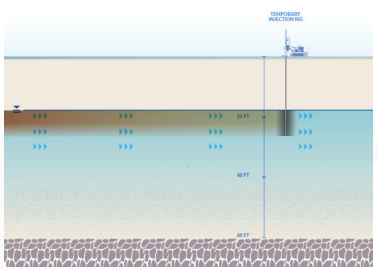
Two Available Approaches:

PLUME STOP Liquid Activated Carbon
SourceStop

Pump & Treat
Contain plume with pumping

In Situ Remediation
Immobilize the PFAS within the aquifer



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Remediation by Immobilization

*"Remediation is a process used to reduce or eliminate the risk for humans and the environment that may result from exposure to harmful chemicals" **

*Interstate Technology Regulatory Council (ITRC), 2020

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Risk

Risk is eliminated if there is no potential for exposure to a hazard

PFAS = PFAS Hazard × Potential for Exposure

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In Situ Remediation Using Colloidal Activated Carbon

- Form of activated carbon
- Particle sizes 1 – 2 µm
- Suspended as a colloid in a polymer solution
- Distributes widely under low pressure
- Provides extremely fast sorption sites
- Converts underlying geology into purifying filter

PLUME STOP Liquid Activated Carbon

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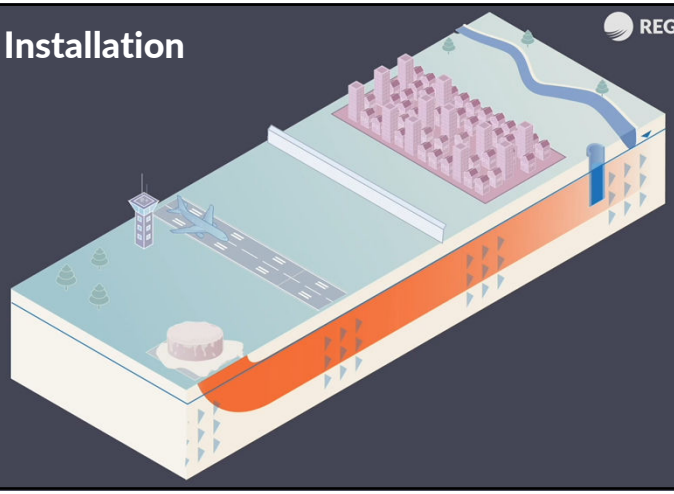
CAC Installation



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PlumeStop

PLUME STOP
Liquid Activated Carbon

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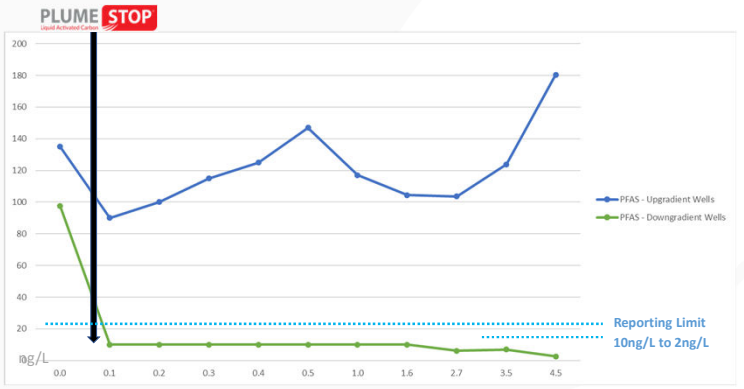
Efficacy: Example Results



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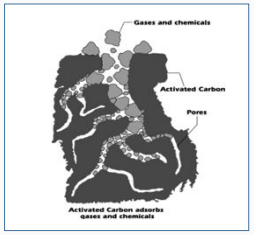
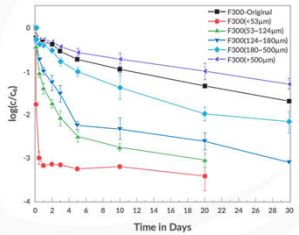
How is PlumeStop Different from GAC?





- Smaller particles provides more exterior surface
- Shorter distance to sorption sites
- Rapid and efficient sorption

Xiao, Ulrich, Chen & Higgins. Environ. Sci. Technol. 2017, 51, 6342-6351

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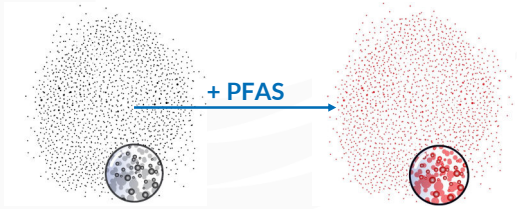
Particle Cross Section Illustration

- Granular Activated Carbon
  - > 300 µm
  - Slow sorption due to limited surface area exposed to solute
- Colloidal Activated Carbon
  - 1-2 µm
  - Rapid sorption due to high surface area and more complete use of sorption sites



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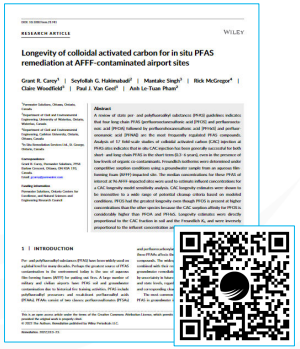
Effectiveness: Third Party Assessment

- Review of 17 field applications showing successful remediation
- Co-contaminants present (PH, CHC's)
- Modeling indicates decades of treatment longevity (single injection)
- Short-chain PFAS
  - Will sorb to some small degree
  - Longer-chain PFAS drive risk – sorb well


RESEARCH ARTICLE

WILEY

Longevity of colloidal activated carbon for in situ PFAS remediation at AFFF-contaminated airport sites

Grant R. Carey[1] | Seyfollah G. Hakimabadi[2] | Mantalav Singh[1] | Rick McGregor[1] | Claire Woodfield[1] | Paul J. Van Geel[2] | Anh Le-Tuan Pham[2]

Abstract

1 | INTRODUCTION

1. Carey, G.R., et. al. 2022. Remediation, 33: 3-23

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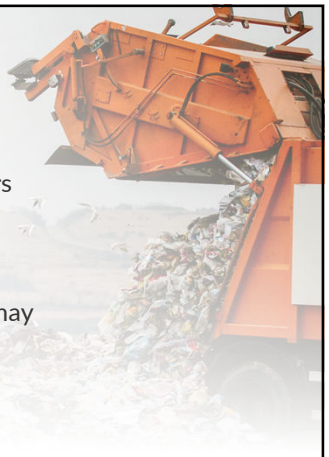
What are Possible Limitations?



- Plumes with lots of hydrophobic competitors
  - (e.g. high BOD landfill leachate)
- Very fast plumes in clean aquifer media
  - (e.g. washed cobbles)
- Very deep plumes where installation costs may become prohibitive
  - (e.g. >200')

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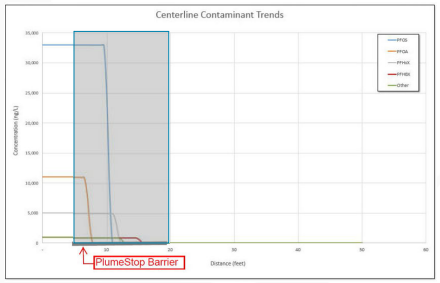
How do you Design the Remediation?

Barrier lifespan modelled on isotherms, dynamic sorption

Dose based on:

- Target contaminant flux
- Competitive sorption
  - Other contaminants
  - Natural organics (will degrade)



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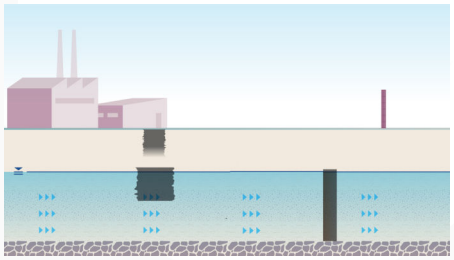
What is the Expected Longevity?

Assuming a constant incoming flux of PFAS:

- Researchers have estimated decades of performance longevity[1]
- Re-injection will start the clock over
- Targeted partial re-injection may suffice[2]

What if you treat the source?

- Diminishing influx of PFAS
- No further treatment may be needed[3]



1. Carey, G.R., et. al. 2019. Remediation, 29: 17-31
2. Carey, G. R., et. al. 2023. Remediation, 34: 1-18
3. Newell, CJ. et. al., 2022 Remediation, 32 (4):239-257

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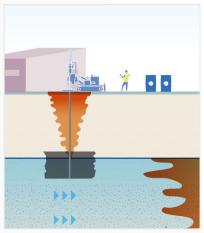
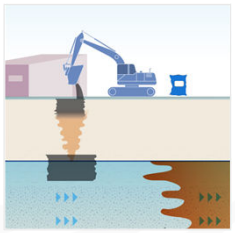
Targeting PFAS Sources

Stabilizes PFAS sorbed to soils in the vadose zone



Stabilizes PFAS sorbed to air water interface in capillary fringe

Sorbs dissolved contamination in the groundwater



Combined treatment prevents further discharge

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PFAS Source Zone Treatment

SourceStop®

- Stabilizes PFAS Source Areas
- Reduces leaching of soil contamination
- Halts migration of PFAS in groundwater

Available in two formulations:

Liquid

Solid

Both use REGENESIS' Colloidal Activated Carbon

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Distribution and Coating

- When mixed into moist soils:
  - Colloidal Activated Carbon released
  - Enhancing distribution
  - Penetrating and coating soils
    - Important for silty/clayey soils
  - Rapidly effective
  - Easy visual confirmation minimizes mixing time and cost

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Field Application

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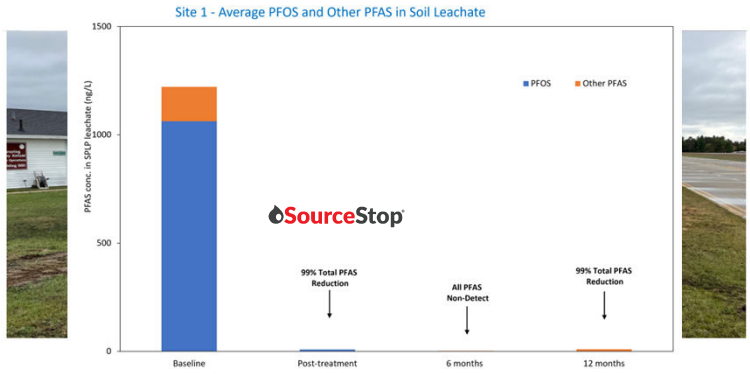
Effect on Leachability: Grayling, MI



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What is the Cost?

Small Industrial Project, Canada

PlumeStop barrier: $73K
(O&M = $0/year)

Estimated P&T: $1.35M
(Installation: $150K)
(O&M: $63K x 20 years= $1.2M)

R. McGregor, ISRL, 2018

Large Refinery Project, Michigan

PlumeStop barrier: $3.5M

Estimated P&T + Sheet pile: $20M+

R. Mora, 2023, presentation at Symposium on Bioremediation and Sustainable Environmental Technologies, Battelle

Less than 1/3 the Cost of Pump and Treat

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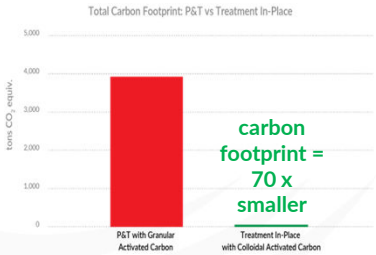
Social and Environmental Impact

- >95% reduction in greenhouse gas emissions[1]
- Highly resilient (no electricity or moving parts)
- No contamination brought to surface
- No waste created



carbon footprint = 70 x smaller

1. Ramboll 2023 Sustainability-Case-study-PlumeStop-vs-PT-Final.pdf

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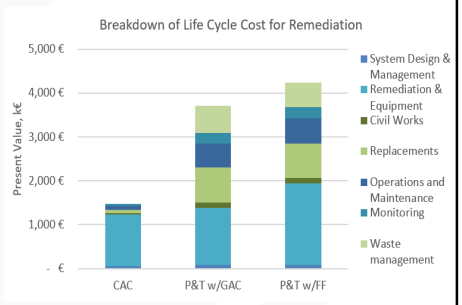
Life Cycle Cost Analysis

- Pricing analysis by Ramboll
- Based on a 15-year treatment
- Costs at different times throughout
- Net Present Value:

CAC retention barrier = $1.608M
P&T with GAC = $4.039M
P&T with FF = $4.623M



61-65% less

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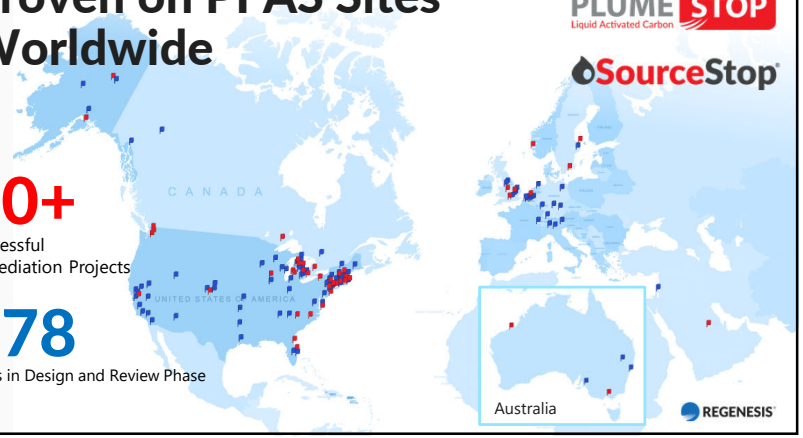
Proven on PFAS Sites Worldwide

PLUME STOP Liquid Activated Carbon

SourceStop



60+
Successful Remediation Projects

178
Sites in Design and Review Phase

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PFAS Source & Plume: Issues and Solutions

Figure Key

A: Vadose soil
B: Capillary Fringe
C: Source Groundwater
D: Dilute Plume

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Summary

Emerging as the default solution for PFAS contaminated sites

- Proven to achieve and maintain EPA MCLs
- No PFAS waste generated
- No lingering exposure risk
- Very low cost
- Warrantied Performance

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Questions?

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