REGENESIS®

7 Reasons

To Choose *In Situ* PFAS Remediation

Introduction

Two Treatment Options for PFAS in Groundwater

There are two options for treating PFAS in groundwater, based on where the treatment occurs. The first is groundwater extraction and treatment, commonly known as pump-and-treat. This method involves using mechanical systems to pump PFAS-contaminated groundwater to the surface, where it is treated using separation technologies like granular activated carbon, ion exchange, or foam fractionation.

The second option is *in situ* remediation, which treats PFAS contaminants directly below the ground surface. This remediation alternative converts the aquifer into a subsurface filter by applying a technological innovation known as colloidal activated carbon (CAC), commercially offered as PlumeStop® and SourceStop®.

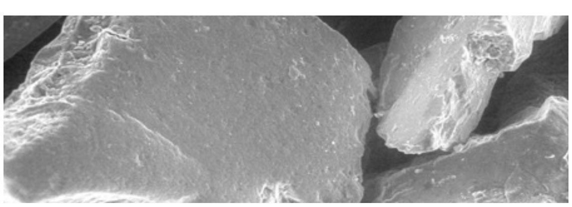
In simple terms, preventing PFAS exposure risk comes down to a choice between treating PFAS aboveground or belowground. Both options are considered PFAS remediation, preventing the migration of these chemicals to eliminate or reduce the exposure risk (ITRC, 2020). However, the choice between aboveground or belowground approaches can have significant and lasting consequences relating to cost, community protection, and long-term liabilities for site owners, operators, and responsible parties dealing with PFAS contamination in groundwater.

What is Colloidal Activated Carbon and How Does it Treat PFAS?

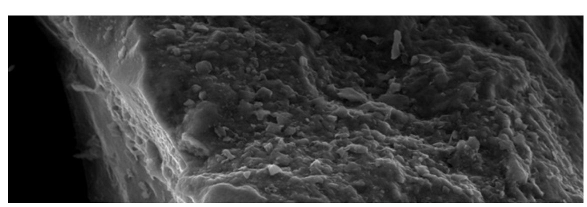
Colloidal activated carbon or CAC is a patented technology commercially available as PlumeStop and SourceStop, applied for groundwater plume treatments and to address PFAS source areas, respectively. These CAC materials are composed of <2-micron diameter activated carbon particles dispersed in a water-based medium to create a liquid, colloidal form of activated carbon.

PlumeStop is a liquid, CAC amendment developed for easy injection and subsurface distribution.

When it is injected or mixed into the subsurface, CAC permanently coats the soils with the micro-scale carbon particles. PFAS sorbs much more strongly to CAC than to the native soil organic carbon. Therefore, where CAC is applied, the retardation of PFAS is dramatically increased, typically by multiple orders of magnitude. Groundwater PFAS concentrations are reduced by a corresponding degree, effectively stopping further PFAS plume migration or plume development.



Scanning electron microscope image of sand grains untreated (scale is 50 microns).



Scanning electron microscope image of sand grains coated with CAC (scale is 20 microns).

REGENESIS®

7 Reasons to Remediate PFAS *In Situ* Using Advanced CAC Technologies

When deciding whether to treat PFAS aboveground or belowground, *in situ* remediation using PlumeStop and SourceStop advanced colloidal technologies has numerous advantages over pump-and-treat, including these seven key benefits.

1 **Low Cost:** *In situ* remediation is the lowest-cost option, representing less than 1/3 the cost vs. a pump and treat solution, which minimizes the financial burdens for site owners.

2 **Zero PFAS Waste Produced:** The process generates no PFAS waste materials, eliminating the need for disposal or treatment. This eliminates potential future exposures for communities and long-term liabilities for site stakeholders.

3 **Fast Implementation with no Maintenance:** With no permanent equipment to maintain, *in situ* remediation simplifies the process and eliminates the need for ongoing operation & maintenance (O&M) visits merely to keep the systems running.

4 **Immediate Results:** Treatments immediately begin removing contaminants from groundwater, consistently achieving regulatory standards by the first monitoring event.

5 **Long-Term Effectiveness:** *In situ* remediation provides sustained protection for decades or even permanently, ensuring lasting impact.

6 **Significantly Lower Carbon Footprint:** The process is environmentally friendly, reducing greenhouse gas emissions by 98 percent compared to pump-and-treat.

7 **Field-Tested and Proven:** *In situ* remediation has a well-established track record of success, backed by over 55 real-world applications that validate its reliability.

In the following sections, we explore these seven reasons in greater depth, demonstrating why *in situ* remediation is the most effective approach for addressing PFAS contamination in groundwater.

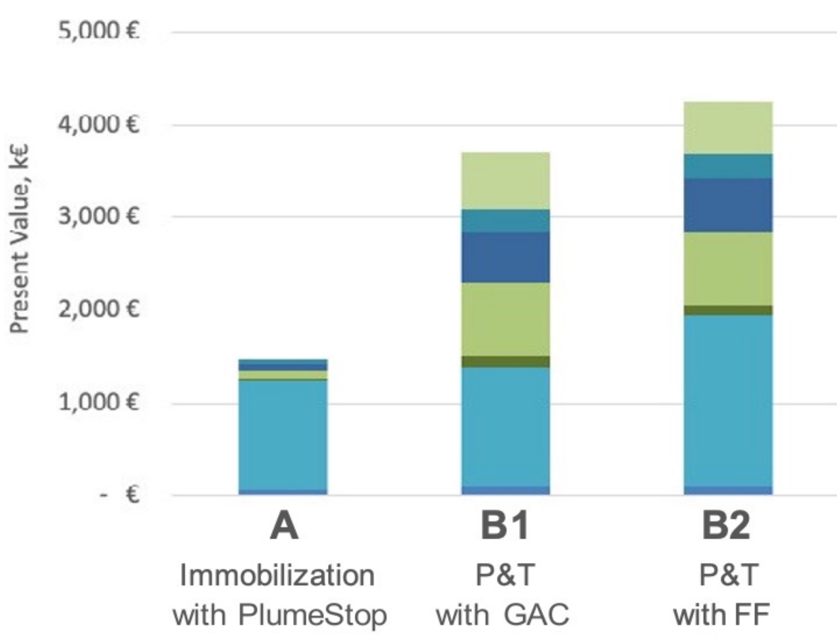
1 Low Cost

In Situ Remediation is Less than ⅓ the Cost of Pump-and-Treat

In situ remediation has consistently proven to be the most cost-effective option in direct comparisons with pump-and-treat methods. For instance, at an airport site in the United Kingdom, a Life Cycle Cost Analysis revealed that the PlumeStop *in situ* approach was one-third of the cost, based on a projected 15-year remediation lifecycle (Ramboll, 2023). Similarly, at an industrial site in the Midwest US, implementing a PlumeStop barrier approach to prevent offsite PFAS plume migration reduces remediation costs by 85% compared to pump-and-treat, with estimated project savings of approximately $17 million. These projects are only a few examples demonstrating the significant cost savings of *in situ* remediation.

Figure 1 Breakdown of Life Cycle Cost for Remediation

Cost analysis comparing in situ remediation (immobilization with PlumeStop) with two pump-and-treat alternatives using granular activated carbon (P&T with GAC) and foam fractionation (P&T with FF) over a 15-year project lifecycle on a United Kingdom airport site.



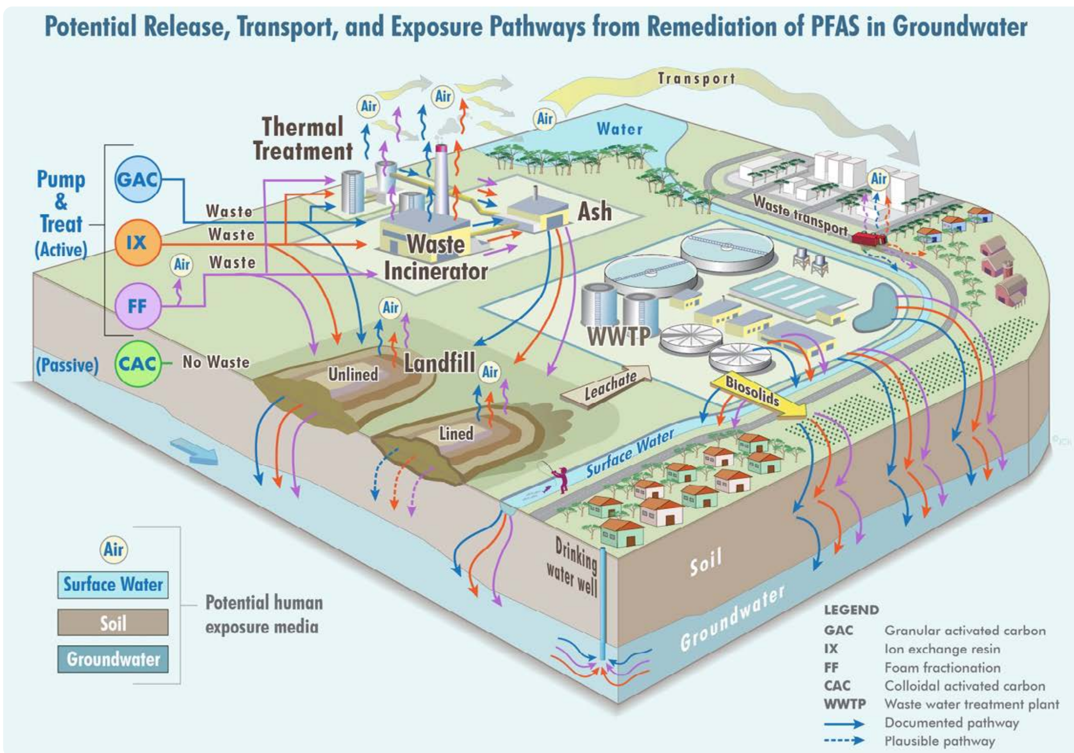
Zero Waste

2 Zero Waste

In Situ Remediation Avoids PFAS Waste, Prevents Future Liabilities

Pump-and-treat systems extract water, which is treated at the surface using granular activated carbon, ion exchange, or foam fractionation technologies. This aboveground treatment process generates concentrated PFAS waste byproducts, containing toxic PFAS compounds, often including the recently designated CERCLA hazardous substances PFOA and PFOS.

Solid waste generated by pump-and-treat must be managed, transported, and disposed of in a landfill or treated using thermal combustion methods. Due to the extreme persistence and toxicity of PFAS chemicals, pumping PFAS-contaminated groundwater aboveground opens a Pandora's Box of potential exposures for individuals and communities (Hall, et al. 2024). Moreover, even when direct exposure is avoided, opening this box can entangle site owners and responsible parties in legal liabilities, including Strict Liability and Joint and Several Liability under CERCLA. Alternatively, treating PFAS below the surface using PlumeStop and SourceStop CAC technologies avoids these long-term exposure risks and liabilities.



Potential release, transport, and exposure pathways from remediation of PFAS in groundwater - Figure reproduced from Hall, et al. (2024).

3 Fast Implementation with No Long-Term Operation & Maintenance

Onsite Treatments Completed in Days to Weeks with No Ongoing Maintenance Needed and No Downtime

Pump-and-treat systems must be kept running in perpetuity (i.e., decades or longer) and require continuous maintenance to remain operational. These systems typically average about 5% downtime, which can cause treatment gaps and additional exposure risks over their decades-long operational lifecycle.

In contrast, most *in situ* remediation projects for PFAS are typically completed in the field within days to weeks. Once installed, PlumeStop and SourceStop remedies continue working through their design life without time-consuming, costly O&M and zero downtime. Considering a PFAS remediation site with a 30-year project lifecycle, *in situ* remediation would eliminate 120 quarterly O&M visits, including mobilization and reporting. Further, since *in situ* remediation does not discharge water to the surface, there is zero risk of Notice of Violations (NOVs) for National Pollutant Discharge Elimination System (NPDES)-permitted discharges that do not achieve the low and difficult-to-attain parts-per-trillion-level discharge limits for PFAS.

REGENESIS®

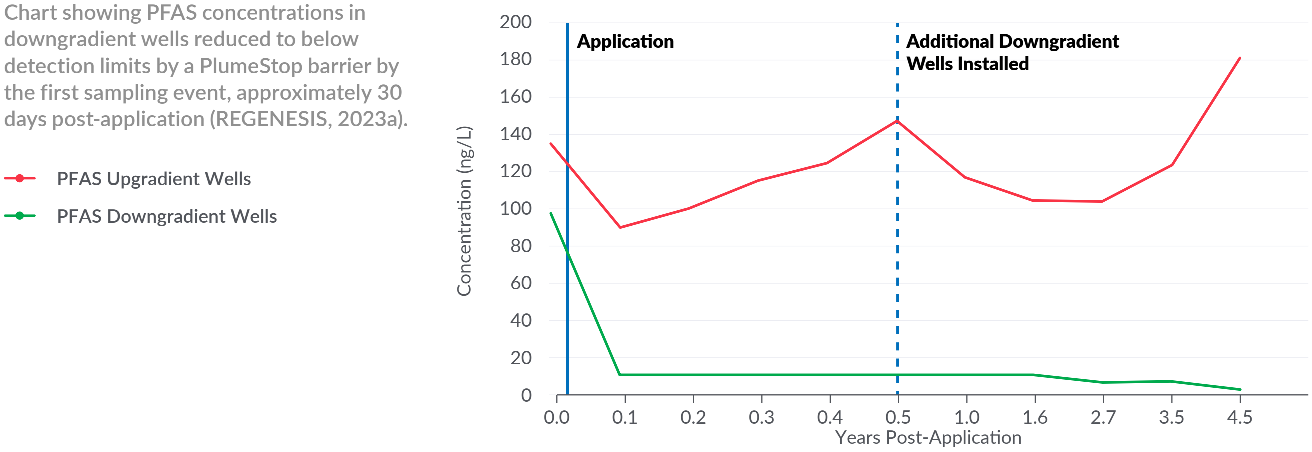
4 Immediate Results

PFAS Removed from Groundwater by First Sampling Event

PlumeStop and SourceStop work immediately in the subsurface to remove PFAS from groundwater. Samples collected from monitoring wells in a treatment zone typically show concentrations reduced to non-detect or near detection limits by the first sampling event, usually within one to three months following application.

Figure 2 PFAS Concentrations Over Time

Chart showing PFAS concentrations in downgradient wells reduced to below detection limits by a PlumeStop barrier by the first sampling event, approximately 30 days post-application (REGENESIS, 2023a).



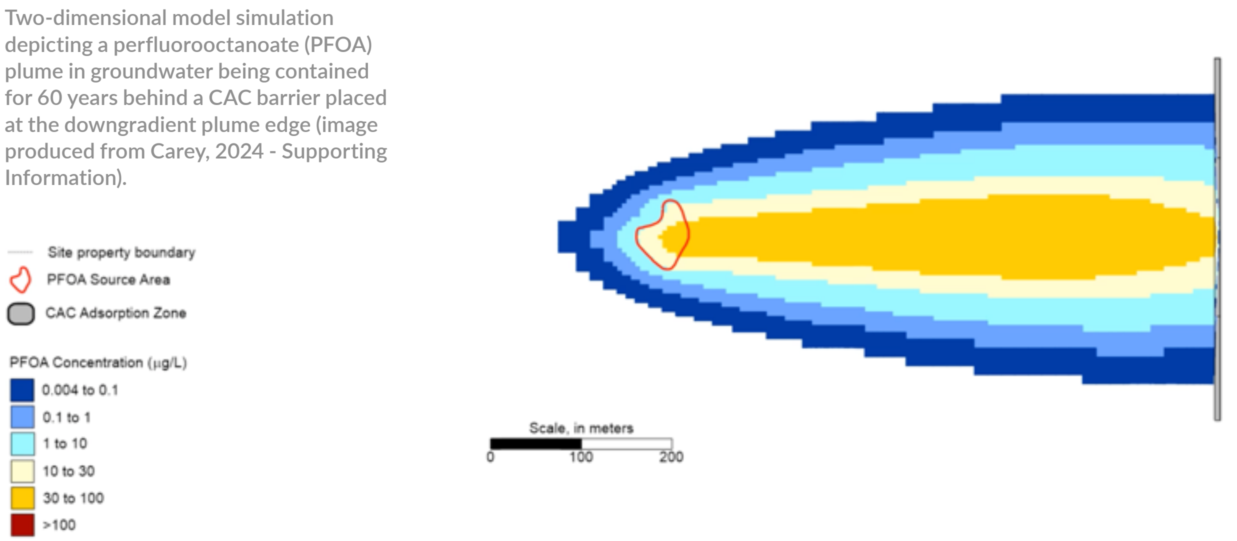
5 Long-Term Effectiveness

In Situ PFAS Remediation Solutions are Designed to Last Decades or Longer

Dr. Grant Carey, an industry-leading groundwater fate and transport and modeling expert, has shown in multiple Department of Defense (DOD)-funded studies that a single injection of CAC can prevent PFAS migration for decades at typical sites impacted by PFAS (Carey et al., 2019, 2022, and 2024). One of these sites, a high-concentration PFAS site at a military facility, shows that a CAC permeable barrier can prevent a large advancing PFAS contaminant groundwater plume from migrating for over 60 years. In the process, two billion liters of groundwater would be treated to non-detect PFAS levels without pumping or waste generation (Carey et al., 2024). If after 60 years, further remediation is required, a simple reinjection would start the clock over again. Additionally, combining source area treatments with SourceStop and plume treatments with PlumeStop may result in a permanent one-and-done solution in many cases.

Figure 3 **Groundwater Plume Containment Model**

Two-dimensional model simulation depicting a perfluorooctanoate (PFOA) plume in groundwater being contained for 60 years behind a CAC barrier placed at the downgradient plume edge (image produced from Carey, 2024 - Supporting Information).



REGENESIS®

6

Low Carbon Footprint

In Situ PFAS Treatment Reduces Carbon Emissions by >98% Compared to Pump-and-Treat

The carbon footprints of *in situ* remediation with PlumeStop vs. two pump-and-treat alternatives were evaluated as part of a Life Cycle Assessment (LCA) for a PFAS groundwater remediation project in the United Kingdom (Ramboll, 2023). Based on this study, the PlumeStop barrier implemented at the site had a 98% lower carbon footprint than pump-and-treat, achieved by avoiding pumping, treating, and discharging >200 million gallons of water and managing PFAS waste. In its first year of operation, the PlumeStop CAC barrier successfully remediated 5,000,000 gallons of PFAS-contaminated groundwater with zero emissions, powered only by naturally occurring groundwater flow.

7 Field Tested and Proven

Over 55 Sites Successfully Remediated

To date, *in situ* remediation of PFAS using PlumeStop and SourceStop CAC technologies has been implemented at over 55 sites in eight countries spanning four continents. The applications completed to date have demonstrated outstanding performance in eliminating PFAS in groundwater with full-scale treatments meeting the project remedial goals. Numerous projects have demonstrated PFAS removal to below or near detection levels for multiple years post-application. These treatments are designed to last many years into the future. Additionally, numerous laboratory and field research projects have been conducted or are in progress under the US Department of Defense's Strategic Environmental Research and Development Program (SERDP) and Environmental Security and Technology Certification Program (ESTCP) (SERDP/ESTCP, n.d.).

Conclusion

The recent regulatory changes imposed by the USEPA will necessitate the remediation of many PFAS-contaminated sites, presenting a choice between aboveground treatment using mechanical pump-and-treat systems and belowground (*in situ*) remediation with PlumeStop and SourceStop advanced colloidal technologies. As highlighted throughout this e-book, the *in situ* remediation approach offers several critical advantages in reducing PFAS exposure risks to people and communities while avoiding the potential long-term risks and liabilities associated with pumping and treating PFAS above the surface. Interested parties should carefully evaluate these factors when choosing a PFAS remediation strategy.

References

1. ATSDR. (n.d.). Potential health effects of PFAS chemicals. U.S. Department of Health and Human Services. Retrieved September 4, 2024, from https://www.atsdr.
d.gov/pfas/health-effects/index.html
2. Carey GR, McGregor R, Pham ALT, Sleep B, Hakimabadi SG. (2019). Evaluating the longevity of a PFAS *in situ* colloidal activated carbon remedy. Remediation, 29(2):17-
31. https://doi.org/10.1002/rem.21593
3. Carey GR, Hakimabadi SG, Singh M, et al. (2022). Longevity of colloidal activated carbon for *in situ* PFAS remediation at AFFF-contaminated airport sites. Remediation, 33(1):3-23. https://doi:10.1002/rem.21741
4. Carey, GR, Anderson, RH, Van Geel, P, et al. (2024). Analysis of colloidal activated carbon alternatives for *in situ* remediation of a large PFAS plume and source area. Remediation, 34, e21772. https://doi.org/10.1002/rem.21772
5. Designation of Perfluorooctanoic Acid (PFOA) and Perfluorooctanesulfonic Acid (PFOS) as CERCLA Hazardous Substances, 89 Fed. Reg. 39124 (May 8, 2024). https://www.federalregister.gov/documents/2024/05/08/2024-08547/designation-of-perfluorooctanoic-acid-pfoa-and-perfluorooctanesulfonic-acid-pfos-as-cercla-hazardous
6. Hall, L. C., Wilson, J. T., & Birnstingl, J. G. A. (2024). Pandora's PFAS box: Life cycle exposure considerations of treatment options for PFAS in groundwater. Remediation, 34, e21775. https://doi.org/10.1002/rem.21775
7. Interstate Technology and Regulatory Council (ITRC). (2020). PFAS Remediation [Video]. YouTube. https://www.youtube.com/watch?v=2OEeJ9qR9nA
8. Ramboll. (2023). Sustainability Assessment of *In Situ* and *Ex Situ* Remediation of PFAS Contaminated Groundwater [PDF Document]. https://regenesis.com/wp-content/uploads/2019/12/Sustainability-Case-study-PlumeStop-vs-PT-Final.pdf
9. REGENESIS. (2023). Case Study: PFAS Eliminated for 4.5 Years and Counting. https://regenesis.com/en/project/pilot-test-conducted-to-remove-pfas-risk/
10. Salvatore D, Mok K, Garrett KK, et al. (2022) Presumptive Contamination: A New Approach to PFAS Contamination Based on Likely Sources. Environmental Science & Technology Letters. Published online October 12, 2022. https://doi:10.1021/acs. estlett.2c00502
11. Strategic Environmental Research and Development Program (SERDP) and Environmental Security and Technology Certification Program (ESTCP) (n.d.). Per- and Polyfluoroalkyl Substances & Aqueous Film-Forming Foam. (n.d.). https://serdp-estcp.mil/focusareas/e18ec5da-d0de-47da-99f9-a07328558149/pfas-afff

REGENESIS®
www.REGENESIS.com