PFAS REMOVED FROM AQUIFER AT HAZARDOUS SITE WHERE AFFF WAS USED

CASE STUDY:
Results Demonstrate 99.9% Reduction of High Concentrations of PFOS & PFOA

Introduction

Use of AFFF for Treating a Large Fire Impacts Aquifer and Nearby Wells

Timeline

1980s
AFFF used to extinguish a large fire

2016
Sampling discovered PFAS in public and domestic wells

2016 - 2020
Investigation and remedial planning phases

2020
PADEP approves PlumeStop pilot study to treat PFAS

February 2021
RRS performs clear water injection test and dye tracer study

April 2021
RRS installs PlumeStop PRB, performance monitoring period begins

A Pennsylvania Hazardous Site Cleanup Act (HSCA) site where aqueous film-forming foam (AFFF) extinguished a large fire in the 1980s was the target of an innovative pilot study to address per- and polyfluoroalkyl substances (PFAS). In 2016, a public supply well in the area was found to contain combined concentrations of perfluorooctanesulfonic (PFOS) and perfluorooctanoic acid (PFOA) exceeding the Environmental Protection Agency's (EPA) 70 parts per trillion (ppt) Health Advisory Level (HAL). Another public supply well was found to contain combined concentrations slightly below the HAL. Upon notification, the affected wells were taken offline and the Pennsylvania Department of Environmental Protection (PADEP) immediately investigated the surrounding area.

The subsequent investigation revealed that PFOA and PFOS had impacted groundwater, resulting from the chemicals contained in the spent AFFF migrating through the surficial soils and underlying fractured bedrock at the site. In addition to the public supply wells, several potable drinking water wells in the area extracting groundwater from the bedrock aquifer were affected. Filtration systems were promptly installed on the affected domestic wells.

With the immediate threats to drinking water addressed, attention turned to strategies that could prevent the further spread of PFOS and PFOA from the source area. Tetra Tech, Inc., (Tetra Tech) a leading provider of consulting, engineering, and technical services worldwide, conducted the PFAS investigation. Working closely on behalf of the PADEP, Tetra Tech was principally involved in assessing the options and choosing a technology for the pilot test. This effort led to the decision to conduct a pilot study using PlumeStop® a patented colloidal activated carbon amendment known to eliminate the risk of PFAS. With the technology decided, Tetra Tech worked closely with REGENESIS® to collect, evaluate, and compile the data needed to inform the PlumeStop design and application strategy.

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PlumeStop PFAS Remediation Pilot Study

Injection Testing Effectively Used for Design Confirmation

PLUME STOP®
Liquid Activated Carbon

Proven Effective on a Wide Range of Contaminants

- CVOCs
- BTEX, PHCs, TCE, PAHs
- MTBE, BTEX
- TNT
- Pesticides, Herbicides
- PFOA, PFOS

PlumeStop treatments form a massive surface area of one to two micron-sized carbon particles adhered to the aquifer materials. As PFAS-impacted groundwater moves through a PlumeStop treatment zone, these mobile, organic contaminants are removed from the groundwater. Subsequently, the groundwater ingestion exposure pathway is made incomplete, and the risk is nullified. PlumeStop has effectively treated PFAS and other organic contaminants at hundreds of remediation sites worldwide.

The goals of the pilot study were to demonstrate that a PlumeStop *in situ* permeable reactive barrier (PRB) could effectively halt the migration of PFOS and PFOA, moving from the source area (i.e., the historical fire location) at high concentrations. Before the commencement of the pilot test, baseline concentrations in the source area were as high as 90,000 nanograms per liter (ng/L) for PFOS and 1,400 ng/L for PFOA.

The pilot study incorporated an injection test and dye tracer study to develop the remediation design. Following the finalization of the design, the PlumeStop injection was performed.

The primary question going into the pilot test was related to bedrock hydrology. Specifically, the test needed to determine the primary fracture-induced groundwater pathways controlling PFAS movement within the top 100 feet below ground surface (bgs) in this area of the bedrock plume. The injection test and dye tracer study were completed to aid in this determination.

REGENESIS®
REMEDIATION SERVICES
Technology-Based Solutions for the Environment

REGENESIS Remediation Services (RRS) completed the injection test in early 2021, with the results confirming highly variable secondary porosity in the target vertical interval. Generally, decreasing volumetric acceptance and higher injection pressures were observed deeper in the target vertical interval. Hydraulic influence and dye at sufficient concentration were observed in the pilot test monitoring wells during the injection test, confirming the overall injection strategy. Additionally, RRS optimized the injection rate to best maintain low injection pressures and control PlumeStop distribution. From this information, REGENESIS completed the remediation design and prepared for the PlumeStop injection.

PlumeStop Injection

Application Included Innovative Injection Using Straddle Packer System to Isolate Vertical Zones

Injection Summary

Design Type
Permeable Reactive Barrier

Aquifer Material
Fractured Siltstone and Shale

Starting Concentrations

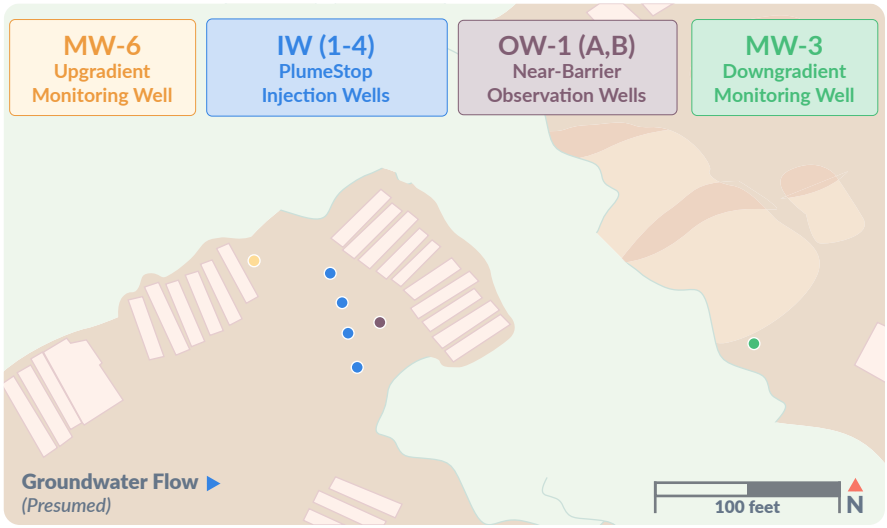
PFOS: 90,000 ng/L	PFOA: 1,400 ng/L

Injection Information

4 Injection Wells	15-87 Feet bgs

PLUME STOP® Liquid Activated Carbon
5,012 Gallons Applied

RRS mobilized to the field in April 2021 to begin the PlumeStop injection. The pilot injection array consisted of 4 injection wells (IW1-4) with non-cased (i.e., open) borehole depths ranging from 15 to 87 feet bgs, an upgradient monitoring well (MW-6) two near-downgradient performance wells, and a more distal downgradient well (MW-3).



Map Depicting PlumeStop - PFAS Remediation Pilot Study Area

Baseline samples for PlumeStop colorimetric testing were collected from two downgradient monitoring wells. PlumeStop was mixed in the RRS injection trailer utilizing two 350-gallon tanks equipped with vortex mixers and pumped using a positive pressure electrically-powered pump.

PlumeStop was injected using a straddle packer system to isolate vertical zones. Based on observed hydraulic responses, an injection sequencing method was applied to properly allocate PlumeStop volumes in the fractured bedrock formation. Water samples were periodically collected from OW-1A, OW-1B, MW-6, and MW-3 and tested for the influence of PlumeStop using a REGENESIS-developed colorimetric field test kit.

REGENESIS Develops a Comprehensive Injection Testing Strategy to Ensure PlumeStop Treatment Success

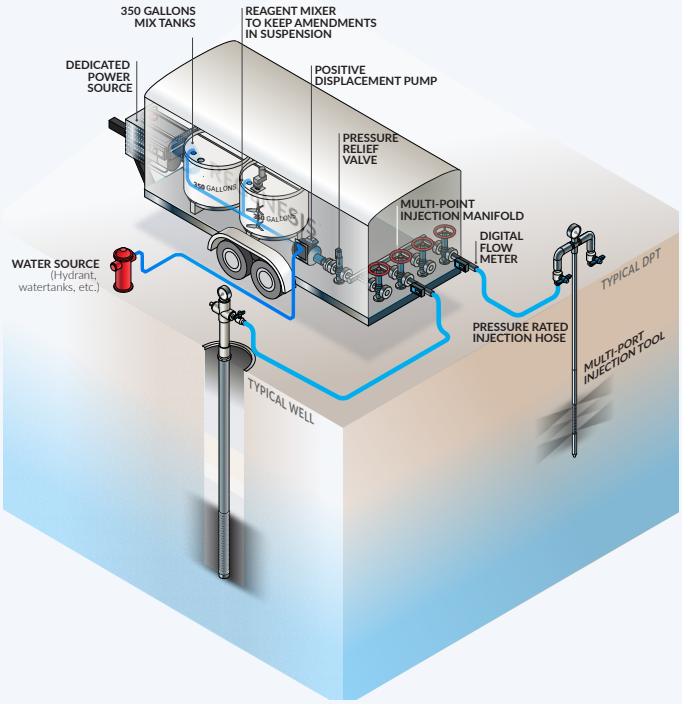
Design verification testing, or DVT, is a REGENESIS program used to verify remediation design parameters prior to implementation. DVT, in this case, included an injection test and dye tracer study. By assessing the formation response to fluid injection over the prescribed depth interval, a PlumeStop injection strategy was developed. The strategy entailed a method for injection interval sequencing, design dosing optimization, and determining volumes and injection flow rates.

The impacted bedrock zone considered for the study encompassed the upper 100 feet below ground surface (bgs), corresponding to the depth interval where the highest PFAS concentrations were observed. The bedrock consists of a sedimentary unit with a complex fracture network, containing sub-horizontal fractures along the bedding plane and sub-vertically oriented fractures. Groundwater movement occurs within these fractures as the primary porosity of the rock is negligible.

This type of hydraulic environment can be challenging for in situ remediation due to the high variability in porosity available to injection. The overall goal of the injection test was to understand the variability, so that a PlumeStop dosing scheme and overall injection delivery strategy for PlumeStop could be developed.

REGENESIS developed the injection testing plan to form a success-oriented injection design and implementation strategy. Considering the remediation area hydrology, components of the injection plan included:

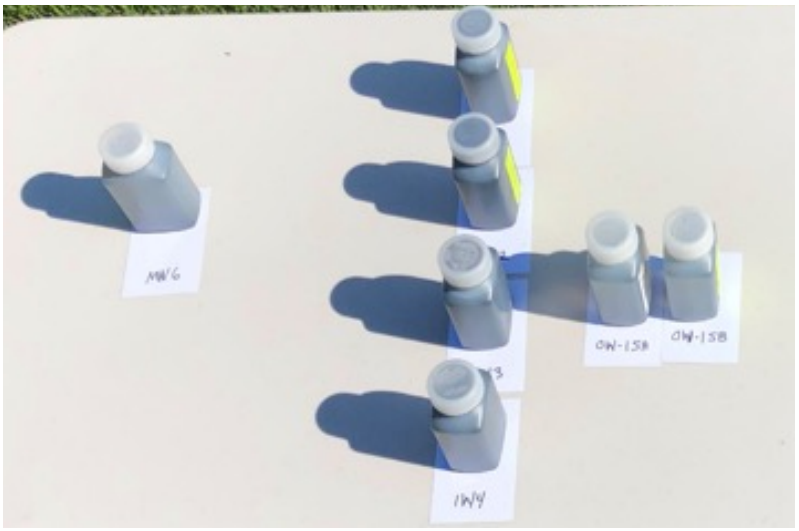
- Examining soil boring and geophysical logs of the injection test wells and nearby observation wells,
- Selecting multiple discretized injection zones surrounding higher flow intervals apparent in both injection wells and nearby observations wells,
- Designing and employing an inflatable packer injection delivery system for isolation of these zones,
- Mixing and injecting batch volumes of clean, potable water mixed with a fluorescent dye and injecting into each zone, moving from the deepest to the shallowest packer-separated injection interval,
- Adjusting flow rates, recording pressure responses, and measuring water level response in nearby observation wells,
- Comparing the batch water dye concentrations to those observed in nearby monitoring wells following injection (analyzed by a third-party lab).



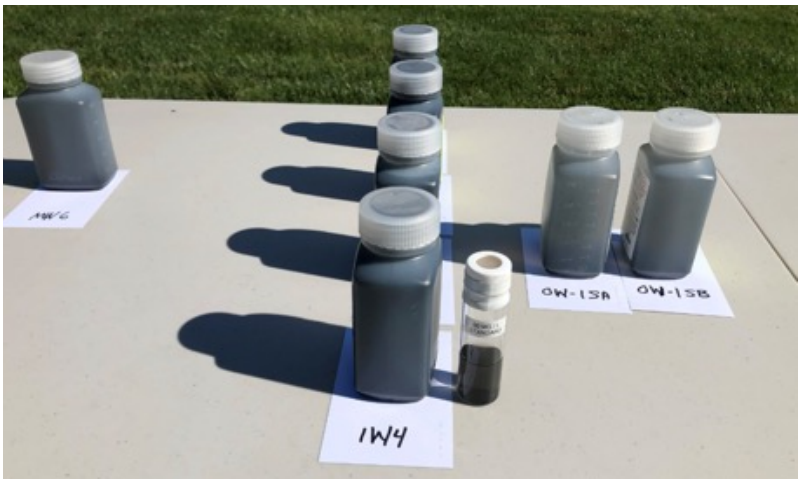
Results

Total PFOS and PFOA reduced from 91,400 to <50 ng/L in One Month

The PlumeStop pilot test injection was successfully completed over a four-day period, safely meeting the project time and budget requirements. During and after injection, PlumeStop influence was observed at near-downgradient observation wells, OW-1A and OW-1B, and at upgradient well MW-6. Over time, water in these wells returned to their baseline color. No influence was noted in the more distal downgradient monitoring well–MW-3. Together, these results validate the deposition of PlumeStop onto the bedrock fracture surface within the designated PRB area.

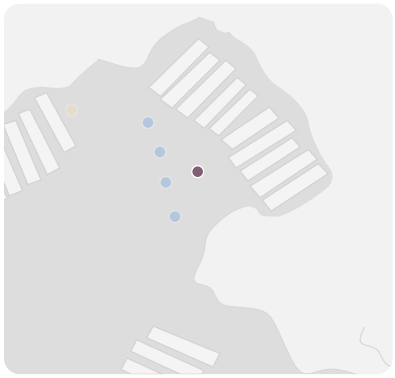


Water in injection wells and nearby observation wells at baseline, before PlumeStop injection

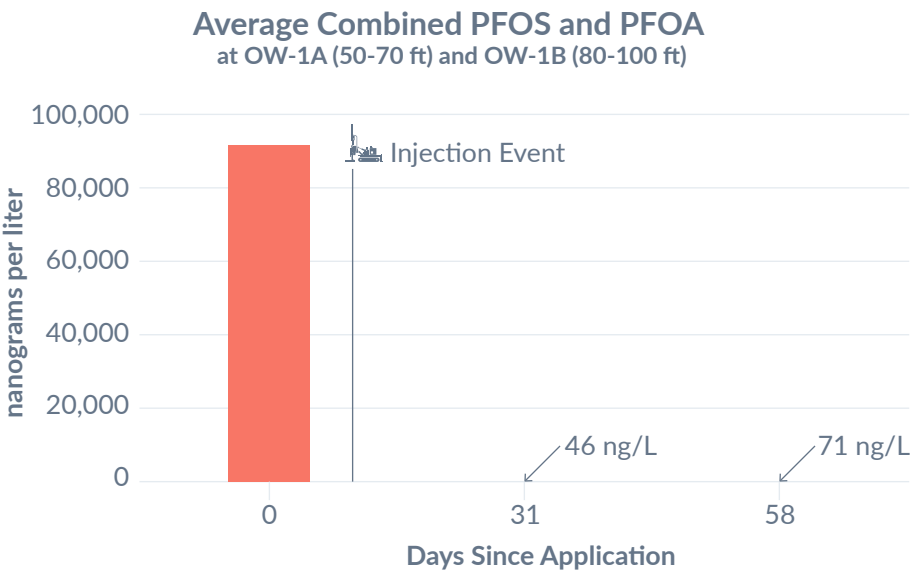


Water in injection wells and nearby observation wells after PlumeStop injection

Laboratory analytical results from the two near-downgradient monitoring wells following the injection have shown a 99.9 percent reduction of PFOS and PFOA through the first two months. This result has demonstrated that a PlumeStop PRB is a viable approach for effectively treating these PFAS at high concentrations in complex bedrock geology.



Location of observation wells OW-1A and OW-1B where PFOS and PFOA concentrations were recorded



Further performance monitoring is scheduled to complete the pilot test. From these early pilot test results and the success of other PlumeStop PFAS remedies, PADEP is considering treating additional impacted areas at the site with PlumeStop.

About The Consultant

Tetra Tech

Tetra Tech has decades of experience providing environmental solutions that are both feasible for our clients and sustainable for our future. Tetra Tech is consistently recognized by Environmental Business Journal and Engineering News-Record as one of the top large businesses working in the environmental industry today. Their fully integrated range of environmental and engineering services allows them to quickly and cost-effectively address their public and private clients' environmental issues.

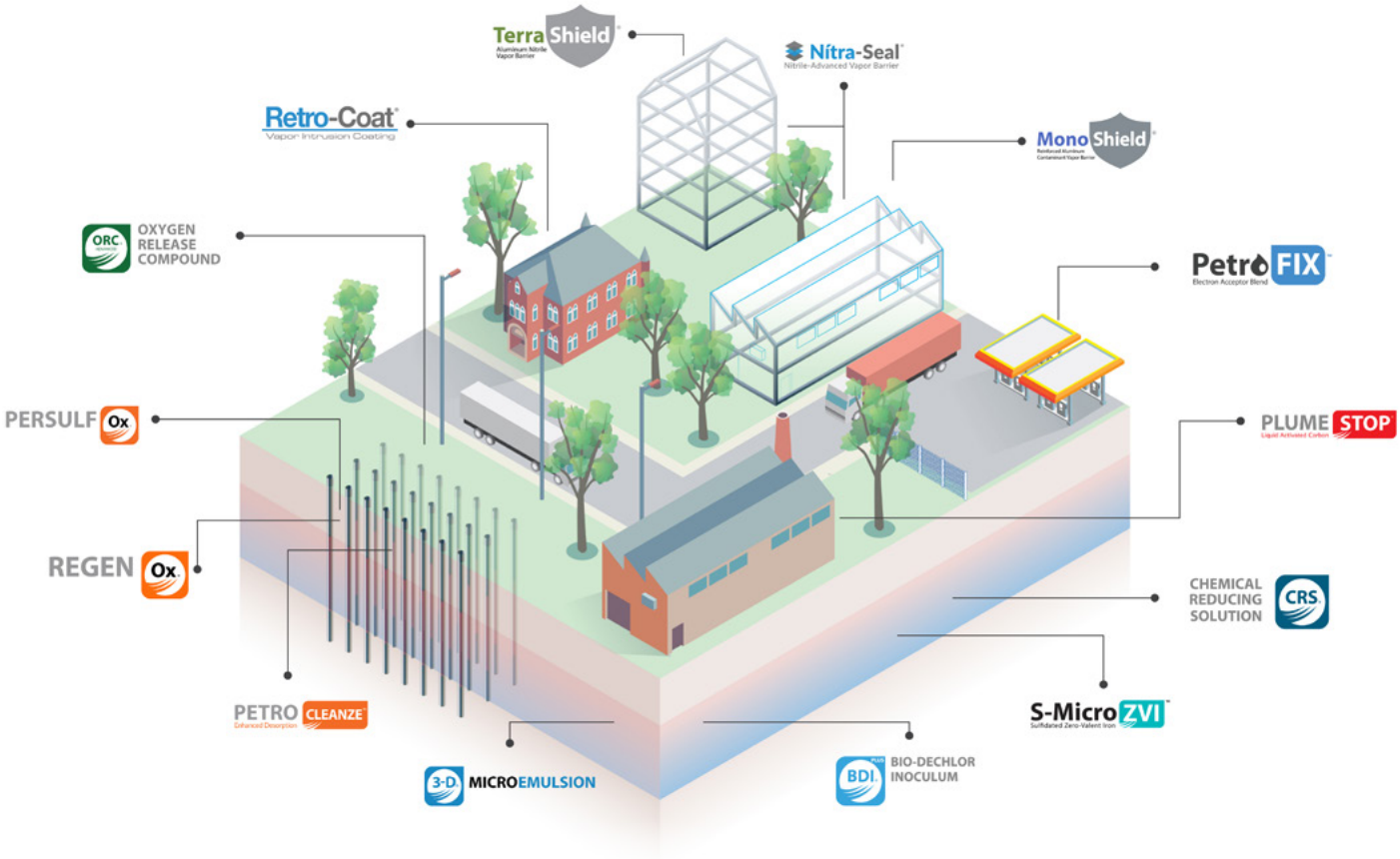
Capabilities include:

- Air Quality
- Environmental Compliance
- Environmental Management
- Environmental Due Diligence
- Industrial Hygiene Sciences
- Remediation

About The Project Manager

Jonathan Dziekan

Mr. Dziekan has 21 years' experience as a Senior Project Manager and civil and environmental engineer for Tetra Tech. He has supported many projects in the field and in the office encompassing civil engineering, environmental engineering, geotechnical engineering, sediments, and various science disciplines. He has supported numerous field- and office-based projects performing project management, environmental facility assessments, construction oversight, resident engineering, field oversight, field engineering, quality control engineering and environmental and safety supervisor duties. He is presently managing projects for private commercial and government clients in the sediments and energy market sectors. He has extensive experience in the renewable energy field on wind, solar, algae-oil and biofuels projects.



About REGENESIS

At REGENESIS we value innovation, technology, expertise and people which together form the unique framework we operate in as an organization. We see innovation and technology as inseparably linked with one being born out of the other.

Inherently, innovation imparts new and better ways of thinking and doing. For us this means delivering expert environmental solutions in the form of the most advanced and effective technologies and services available today.

We value expertise, both our customers' and our own. We find that when our experienced staff collaborates directly with customers on complex problems there is a high potential for success including savings in time, resources and cost.

At REGENESIS we are driven by a strong sense of responsibility to the people charged with managing the complex environmental problems we encounter and to the people involved in developing and implementing our technology-based solutions. We are committed to investing in lasting relationships by taking time to understand the people we work with and their circumstances. We believe this is a key factor in achieving successful project outcomes.

We believe that by acting under this set of values, we can work with our customers to achieve a cleaner, healthier, and more prosperous world.

REGENESIS®

Technologies Used

PlumeStop, A Colloidal Activated Carbon Remedy with Seven Years of Proven Performance

PLUME STOP® Liquid Activated Carbon

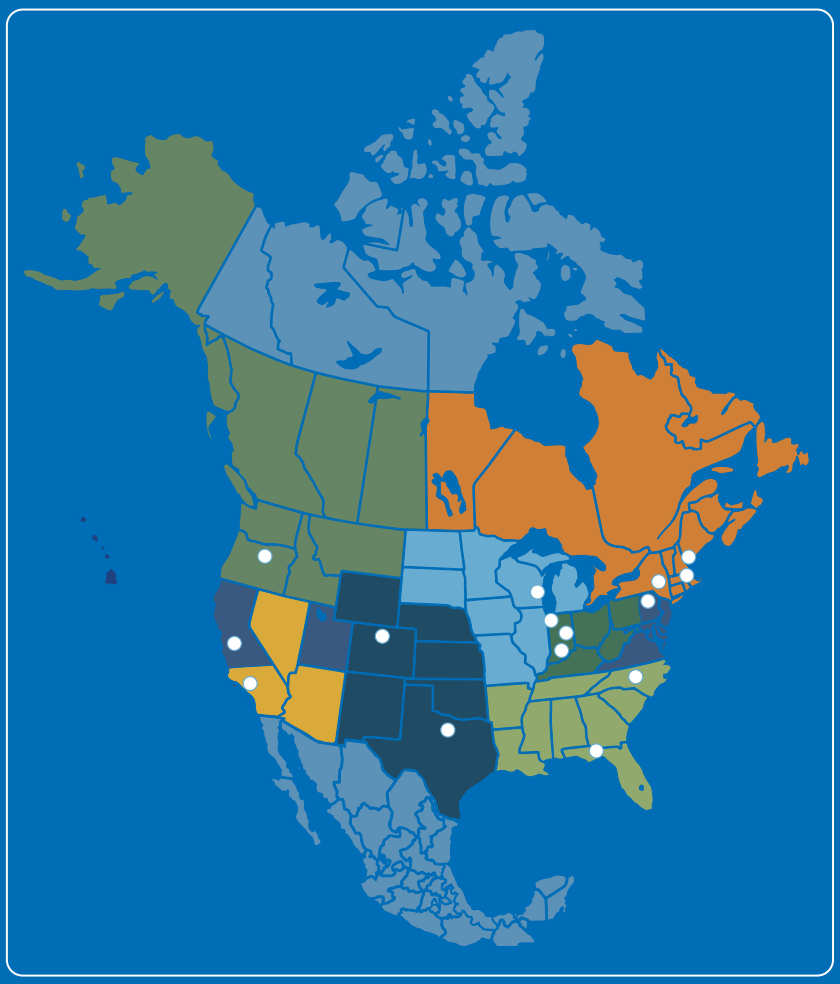
PlumeStop® Colloidal Activated Carbon is a fast-acting groundwater remediation reagent which captures and biodegrades a range of contaminants, thus accelerating the successful treatment of impacted sites and leading to their permanent closure. As a science-based, *in situ* treatment technology, REGENESIS' PlumeStop rapidly removes contaminants from groundwater and stimulates their permanent degradation.

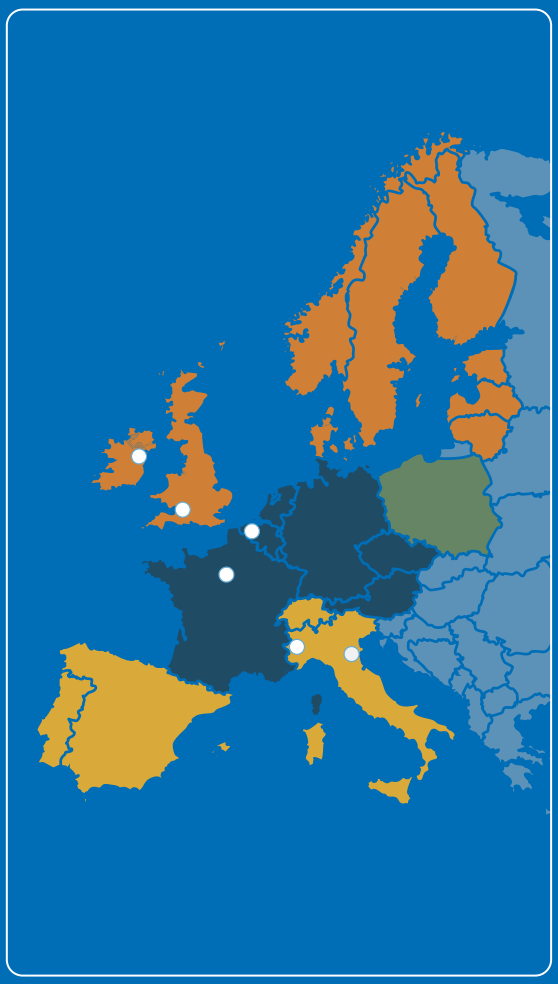
Proven Effective on a Wide Range of Contaminants

- CVOCs
- BTEX, PHCs, TCE, PAHs
- MTBE, BTEX
- TNT
- Pesticides, Herbicides
- PFOA, PFOS

We're Ready to Help You

Find the Right Solution For Your Site





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