REGENESIS®

Regulatory Closure Achieved with Innovative Technologies

Adaptive Bioremediation Strategy Guided by Molecular Tools Resolves 25-Year UST Legacy Using PetroFix



Highlights

Site Type:
Former UST site for fleet vehicle fueling operations

Project Driver:
Persistent petroleum hydrocarbon plume in shallow groundwater (3–6 feet bgs), with proximity to local water supply wells

Contaminants:
Benzene, Naphthalene, C9–C18 Aliphatic Hydrocarbons

Treatment:
Sorption-enhanced natural attenuation, following source zone mass removal and aerobic bioremediation treatments

Technologies:
PetroFix, guided by molecular biological tools (QuantArray®-Petro)

Geology:
Coastal Plain sediments consisting of sand, silt, and clay, including silt and clay lenses

Summary

At a former underground storage tank (UST) site in Wilmington, North Carolina, a history of petroleum contamination posed risks to local supply wells. Despite earlier treatment efforts spanning more than a decade—including excavation and applications of oxygen-releasing and magnesium sulfate compounds—residual benzene and naphthalene persisted in groundwater. A refined remedial strategy guided by biological data led to the successful application of PetroFix®, the first such use in North Carolina. Following the PetroFix application and subsequent monitoring period, concentrations were reduced below the risk-based cleanup objectives, leading to regulatory site closure.

Results

- **Following the PetroFix application and subsequent monitoring period, concentrations were reduced below the risk-based cleanup objectives, leading to regulatory site closure.**



Background

The site was historically used for fueling a fleet of vehicles and included two 4,000-gallon gasoline USTs and one 4,000-gallon diesel UST. After UST decommissioning, the site remained a regulatory concern due to petroleum hydrocarbons in the shallow groundwater and the potential risk to local supply wells.

Remedial actions from 2000 to 2011 included UST removal, soil excavation and ORC Advanced® placement. A monitored natural attenuation (MNA) strategy was implemented to manage the groundwater plume. While the remedial efforts reduced concentrations, residual benzene and naphthalene persisted, especially within low-permeability lenses.

Antea Group Deploys Molecular Biological Tools to Chart Remediation Path Forward

In response, Antea Group, a leading global environmental consulting company, implemented a New Technology Cleanup Plan in 2011, proposing magnesium sulfate injections to stimulate sulfate-reducing bacteria (SRBs) and promote anaerobic degradation.

Subsequent injections (2012–2016) showed encouraging results. Concentrations of C9–C18 aliphatic hydrocarbons declined by over 99% following the amendment applications. Microbial analysis, including QuantArray-Petro offered by Microbial Insights, Inc., demonstrated that the reductions were biologically supported, shown by an increase in sulfate-reducing bacteria and alkyl succinate synthase (assA) genes, which target n-alkanes in the C6–C18 range.

In 2017–2019, ORC Advanced® filter socks were installed in select wells at the request of the regulator to attempt a shift to aerobic conditions. Although the socks generated localized aerobic zones, the site remained largely anaerobic. QuantArray data indicated an increase in aerobic BTEX degraders in treated wells, but a decline in most other anaerobic degraders.

These data suggested that continuing with an aerobic approach would be less effective than enhancing anaerobic bioremediation, which had already shown success at the site. This led Antea Group to propose PetroFix injections which would quickly reduce the dissolved phase contamination but also stimulate anaerobic pathways previously shown to be effective for the site's hydrogeochemistry. PetroFix contains sulfate and nitrate electron acceptors to enhance natural attenuation via anaerobic bioremediation.

Molecular Biological Tools (MBTs) Reveal Microbial Response to Remediation

QuantArray-Petro, a molecular biological tool developed by Microbial Insights to quantify key microbial functional genes, was employed throughout the project to evaluate how microbial populations responded to the different amendment strategies.

Sulfate-Reducing Bacteria (SRBs): QuantArray® detected an increase in dsr and aps genes associated with sulfate reduction following magnesium sulfate injections, supporting enhanced anaerobic biodegradation.

Anaerobic Alkane Degraders: assA genes encoding alkyl succinate synthase also increased post-injection, indicating microbial utilization of n-alkanes in the C6–C18 range, a dominant fraction of diesel-range hydrocarbons.

Aerobic BTEX Degraders: Following ORC Advanced® installation, a localized increase in aerobic BTEX degraders (e.g., tod, xyl, and cat genes) was observed, although broader microbial diversity declined due to the disrupted redox balance.

Collectively, these analytical tools demonstrated that an anaerobic bioremediation strategy was more energetically favorable and would be more effective at achieving site cleanup criteria.

PetroFix Application

PetroFix Application Details	
Application Method	Direct-push injection
Injection Points	41
Volume Applied	16,377 gallons

In 2019, Antea Group pivoted to a sorption-enhanced anaerobic bioremediation approach using PetroFix, marking the first application of this technology in North Carolina. A total of 16,377 gallons of PetroFix solution was injected into 41 points in the treatment zone, targeting areas of highest residual mass. The product's micron-scale particle size (1–2 µm) allowed it to distribute effectively through permeable zones, quickly reducing dissolved-phase concentrations and stimulating anaerobic microbial activity for sustained biodegradation.

To meet North Carolina Department of Environmental Quality (NCDEQ) requirements, PFAS-free groundwater was sourced for mixing with PetroFix. Importantly, Design Verification was conducted during injection activities, using real-time soil coring and groundwater sampling to confirm amendment delivery across the treatment zone and support immediate feedback for field adjustments.

Evidence of daylighting during injection may have also helped treat residual mass in the shallow vadose zone.

Figure 1 PetroFix Injection Grid Layout

PetroFix injection grid layout



Results

Post-application monitoring following the PetroFix application confirmed significant reductions in benzene, with average concentrations dropping to below EPA's Drinking Water Maximum Contaminant Level (MCL) of 5 micrograms per liter (µg/L) in the plume.

The naphthalene trend similarly showed sustained reductions following PetroFix injection with concentrations reducing from an average of 65 µg/L to 4 µg/L. C5-C8 aliphatic petroleum hydrocarbons were also reduced by 88%.

Figure 2 Benzene

Benzene in groundwater pre- and post-PetroFix application

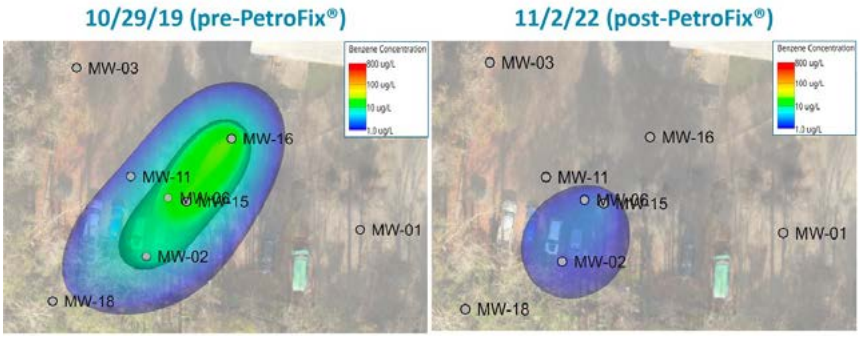
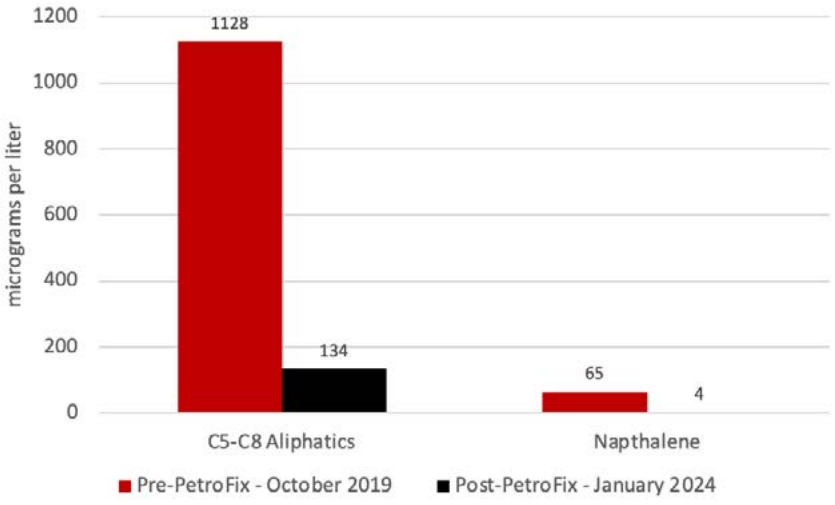


Figure 3 Average C5-C8 Aliphatics and Naphthalene

Average C5-C8 aliphatics and naphthalene concentrations in treatment zone monitoring wells pre- and post-PetroFix injection.



Conclusion

Antea Group's strategic use of molecular biological tools proved essential in tailoring a successful remediation approach at this long-standing UST site. By evaluating microbial community responses throughout the project, the team was able to validate amendment effectiveness, optimize treatment design, and select the appropriate biogeochemical pathway to support natural attenuation.

The PetroFix application not only achieved rapid contaminant reductions but also stimulated the anaerobic biodegradation processes already active in the aquifer. This adaptive, data-driven strategy led to the protection of nearby sensitive receptors and ultimately resulted in regulatory closure—a testament to Antea Group's technical leadership and commitment to science-based environmental restoration.



About the Consultant

Antea Group is an international engineering and environmental consulting firm specializing in full-service solutions in the fields of environment, health and safety, and sustainability. By combining strategic thinking and multidisciplinary perspectives with technical expertise and pragmatic action, we do more than effectively solve client challenges; we deliver sustainable results for a better future. With access to more than 3,000 employees in over 100 offices and experience on six continents, we serve clients ranging from global energy companies and manufacturers to national governments and local municipalities. Understanding today. Improving tomorrow. We have experience in: EHS, Sustainability, Health and Safety, Oil and Gas, Food and Beverage, Railroad, Chemical, Manufacturing, Technology, Water, Compliance, Auditing and more.

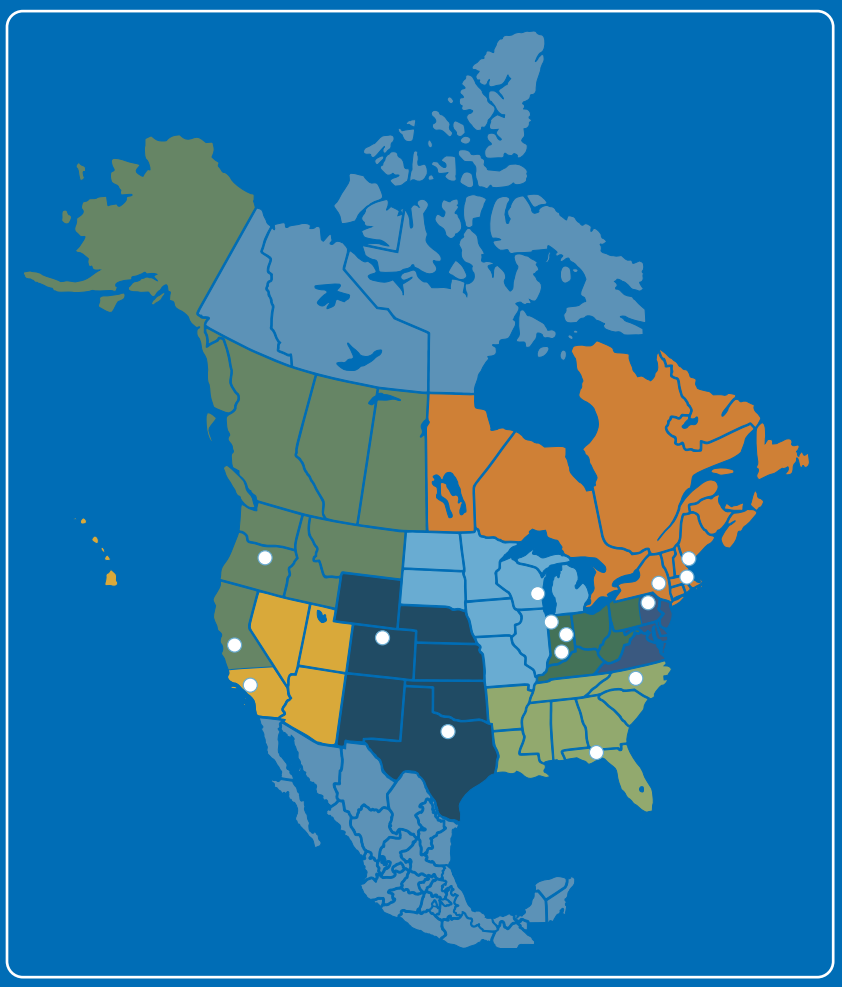


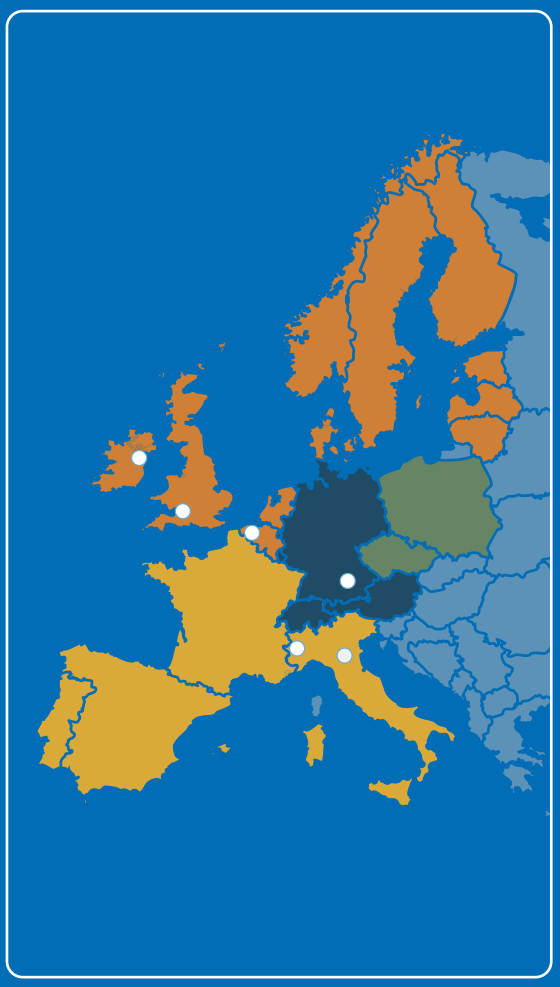
Rob Thompson, PG, RSM | Senior Manager

Rob Thompson has more than 30 years of industry experience. With a focus on site characterization, Conceptual Site Model (CSM) development, remedial design and implementation, and project management, Rob has provided senior technical support for assessment and remediation solutions to private, commercial, industrial, and municipal clients throughout the USA. Rob completed the design and implementation of the largest application of PlumeStop® Liquid Activated Carbon™ at a manufacturing site in North Carolina contaminated with Freon 11 and chlorinated solvents including tetrachloroethene (PCE) and Trichloroethene (TCE). This is globally the largest PlumeStop® application at a site where the dominant constituent in the groundwater plume was Freon 11. Rob also completed the first application of PetroFix® Remediation Fluid at a legacy UST site in Wilmington, North Carolina. With the known impacts of per-and polyfluoroalkyl substances (PFAS) in the Wilmington, NC area, the regulatory agency requested that PFAS-free water be used for the application therefore, a PFAS-free water source was identified and used. As a subject matter expert (SME), Rob provides senior technical support for subsurface injection, remedial evaluations, and remedial implementation for sites contaminated with petroleum hydrocarbons, PCE, and TCE in Alabama, California, Georgia, Florida, Minnesota, Mississippi, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Virginia, Washington, and West Virginia.

Rob is the team leader of the firm's Probabilistic Modeling Services. The Probabilistic Modeling services support external and internal client needs to assess work scopes and to forecast costs for specific sites or portfolios. A significant aspect of the practice area targets asset transactions where a single site or a portfolio of sites requires appropriate scopes of work to be created and defined for endpoints of regulatory acceptance and business financial goals.

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