

TerraStryke® TPHENHANCED™

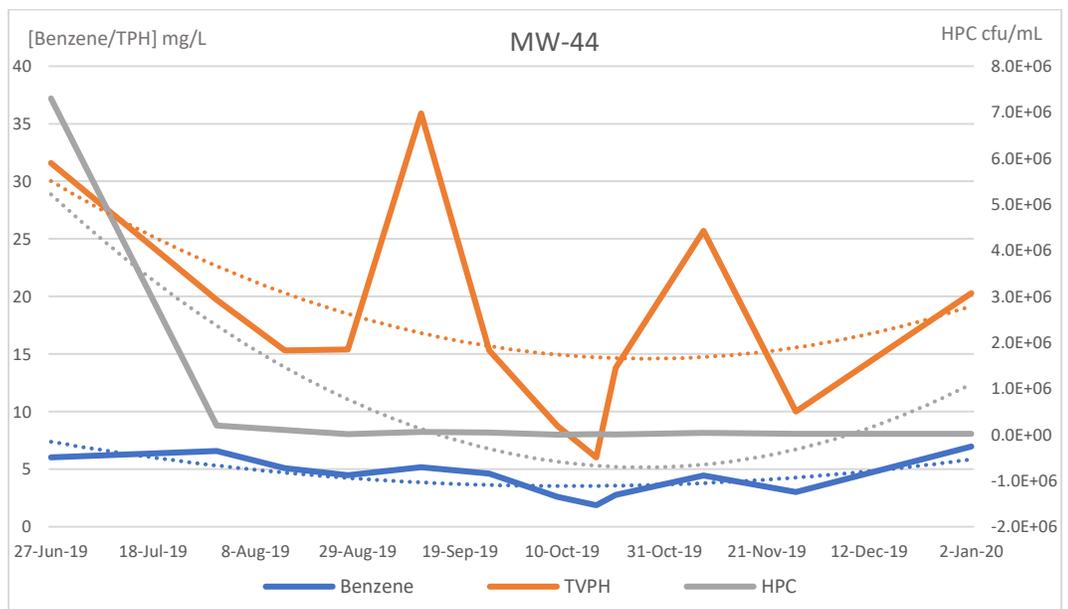
In-Situ Petroleum Hydrocarbon LNAPL Destruction via Biostimulation Alone.

Proof-of-Concept Evaluation Using Simple Additive Delivery Approach

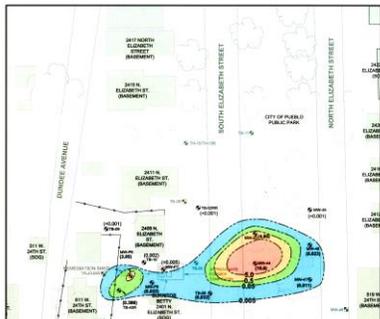
Former Gas Station, Denver CO

TerraStryke® Products LLC develop and distribute biostimulation additives proven to cost-effectively maximize performance at any site using biostimulation alone. Our additives enhance the nutritive capacity of the treatment zone to support indigenous microbial populations ability to expedite contaminant destruction, eliminate rebound, and realize long-term compliance; all with minimal impact and **less cost**. TPHENHANCED provides respiratory pathways *without* O₂ and macro-micro nutrients to support indigenous microbial ability to achieve quorum densities, develop biofilm, and realize sustainable contaminant destruction.

Concern: Total Volatile Petroleum Hydrocarbon (TVPH) contaminants exceeding regulatory guidelines sorbed to saturated soils with downgradient dissolved-phase migration from former UST excavation area into adjacent on-off-site native soils. Contaminant-of-Concern (COC) Benzene. Baseline [Benzene] recorded 6.03 mg/L, [TVPH] at 31.6 mg/L, and swimming/planktonic bulk water Heterotrophic Plate Counts (HPC) at 7.6 x 10⁶ cfu/mL. Regulatory agency and Owner seeking low-impact low-cost solution to legacy issue.



Results: Additive was available throughout the 7-month evaluation until PRS deployments ceased 2-weeks prior to evaluation end. Midway through the evaluation [COCs] realized a 69%↓ and 83%↓ reduction in Benzene and TVPH, respectively. During same time HPC densities *decreased* to BDL. Subsequently, [COCs] continued to trend downward (61%↓ more) while demonstrating periods of solubilization as HPC densities of swimming bacteria returned though remaining 2-3 OM below baseline levels, indicating continued sequestering of non-motile bacteria in the biofilm and the emergence of 'scouts' from the biofilm itself.



Project Highlights

- **TPHENHANCED™** enhances the nutritive capacity of the treatment zone to support indigenous microbial degraders.
- **TPHENHANCED™** supported **>83% REDUCTION** [TVPH] and **>69% REDUCTION** [Benzene]
- **TPHENHANCED™** expedites flux of bound residual source mass to get the rebound out *up-front*.
- **TPHENHANCED™** supports Quorum Sensing and Signaling (QSS), development of biofilm to realize maximum contaminant destruction.
- **TPHENHANCED™** enhances smear-zone and low-perm contaminant bioavailability/destruction.
- Minimize site liabilities and realize low-impact, cost-effective compliance simply by letting Mother Nature have it!

TPHENHANCED™
Cost-Effective
Long-Term
Low-Impact



Proof-of-Concept Study: Implemented in 2019, study designed to identify a sustainable, low-cost, low-impact remedial strategy to address PHC contaminants in all media – soil, soil vapor, and groundwater. Bioremediation, via biostimulation, was determined the appropriate strategy. The cost-effective and environmentally friendly biostimulation additive **TPHENHANCED** by TerraStryke® was chosen as the amending compound; an industry-leading proprietary blend of macro-micro-nutrients formulated with Nitrates, **TPHENHANCED** amends the nutritive capacity of the microbial ecosystem/treatment zone while supporting respiration of indigenous microbial populations under anaerobic conditions. Study designed to evaluate efficacy of biostimulation additive **TPHENHANCED** to enhance native heterotrophic bacteria population's ability to degrade petroleum hydrocarbon contaminants (PHCs) under anaerobic conditions. Site former gas-station converted into fast food restaurant. Underground storage tanks (USTs) removed; however, past use adversely impacted on/off-site saturated soils/groundwater.

Study Process: Limited test zone amended over 7-month period (T₀-T₁₁) using additive filled passive release sock (PRS) deployment units; 2-pounds additive each, 2 units deployed per event. Passively creates ≈3-5-foot area-of-influence (AOI). PRS units are suspended within the saturated screened interval of a monitoring well (MW-44) proximate to an off-site contaminant plume center. PRS units were replaced at ≈2-3 week intervals from July 16, 2019 to December 12, 2020.

Analytical Results: Baseline [Benzene] was 7.73 mg/L, [TVPH] 31.6 mg/L, and Nitrate ([NO₃]) 515 mg/L. Residual source mass (LNAPL) is known present in saturated soils within/outside the limited treatment zone. After first PRS deployment (T₀) availability of additive increases 2-Orders of Magnitude (OM) and remains available throughout the evaluation until PRS replacements are ceased. Expectantly, 4-weeks after first PRS deployments microbial densities increase and dissolved-phase [TVPH] decreased 51.3%. A sharp increase (133%) in [TVPH] was observed 2-weeks later (T₄) only to be followed by a steady decrease for six-weeks (T₇) to realize 83.2%↓ reduction from peak bioavailability; and, after a slight rise (T₀ to T₁) [Benzene] also decrease 69%↓. The decreases in dissolved-phase COCs is attributed to additive enhanced microbial based source mass solubilization (flux to the groundwater) and assimilation of available dissolved-phase carbon, i.e. Site contaminants-of-concern (COC). The last reporting event of the study saw [COCs] begin to increase and ORP levels decrease as additive availability was exhausted.

Microbial Results: Baseline Heterotrophic Plate Counts (HPC) of swimming (planktonic) microbes was noted 7.3×10^6 cfu/mL. As additive availability increased densities of these same microbes *decreased*. At T₇ [TVPH/Benzene] were at their lowest levels and HPC densities measured below detection levels (BDL); i.e., no measurable microbes were in the bulk water sample collected. Is there a direct correlation between density and contaminant availability or was this a result of biofilm development and QSS. We propose, HPC densities achieved 'quorum' levels allowing a signaled change in bulk water populations from a planktonic to sessile form. These sessile microbes collectively establish protective biofilms to maximize energy (proton) utilization. From T₈ through T₁₁ (January 2, 2020) HPC levels return (10^3 - 10^4 cfu/mL) yet remain distinctively 2-3 OM lower than baseline as contaminant assimilation/solubilization continues with [TVPH/Benzene] overall trending downward by an additional 61% during this same period representing a steady state between additive enhanced microbial solubilization of LNAPL mass concurrent with assimilation of the bioavailable dissolved-phase contaminants (protons). Had the nutritive capacity of the treatment zone been maintained longer dissolved-phase [TVPH/Benzene] would continue to trend downward.

Summary: **TPHENHANCED** enriches the ecosystem where microbes reside to eliminate stresses limiting growth, signaling, the development of biofilm and, the initiation of QSS behaviours. In a biofilm microbes establish syntrophic relationships that allow unicellular organisms to combine and unify metabolic capabilities to degrade substrate(s) neither could degrade alone. Numerous bacteria can ferment many different organic compounds; however, most can't 'touch' Hydrogen (H₂). Many Archeae (methanogens) can ferment H₂ and Carbon Dioxide (CO₂) yet most can't 'touch' organic compounds. What does this mean? **Your** realization of expedited site compliance by eliminating rebound out upfront, destroying dissolved-phase contaminants faster organically while, sequestering Greenhouse gasses, all with less-impacts, less-effort, less analytical, and less-cost.