Performance of a New Activated Carbon Amendment for Bioremediating Petroleum-Impacted Sites

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Outline

• Our Company
• Technology Overview
• UST/Service Station Case Studies
• PetroFix Resources
• Design Assistant Walkthrough (time and interest permitting)
WHAT WE DO

We develop cutting-edge technologies to clean up soil and groundwater in-situ.

TECHNOLOGY CLASSES:

• Enhanced Aerobic Biodegradation
• Enhanced Anaerobic Biodegradation
• In Situ Chemical Oxidation (ISCO)
• In Situ Chemical Reduction (ISCR)
• Bioaugmentation
• Metals Immobilization
• In Situ Sorption and Biodegradation

25 Years in Business
CONTINUOUS DEVELOPMENT OF NEW TREATMENT TECHNOLOGIES

- 1995 ORC® Powder/Slurry
- 2000 HRC Primer
- 2002 MRC®
- 2005 ORC Advanced
- 2008 RegenOx®
- 2011 PersulfOx®
- 2011 ORC Advanced Pellets
- 2011 REGENESIS® Remediation Services
- 2019 S-MicroZVI™
- 1994 ORC® Filter Socks
- 1999 HRC®
- 2001 HRC-X®
- 2004 Bio-Dechlor Inoculum® Plus
- 2012 CRS™
- 2010 PetroCleanze™
- 2007 3-D Microemulsion®
- 2014 PlumeStop® Liquid Activated Carbon™
- 2018 PetroFix™
PetroFix Resulted From PlumeStop Research

PlumeStop® Liquid Activated Carbon™ launched in 2013

- Applied on 300+ sites
- Industry leading product for solvents, PFAS, hydrocarbons

Identified an opportunity to evolve the formulation for petroleum sites - PetroFix™

- Fast results for petroleum sites
- Persistent treatment
- Higher treatment range
- Promotes biodegradation after sorption
- Easy and safe to apply
- Do it yourself process (versus turn-key)
Features

• Patented use of **micro-scale activated carbon** (1-2 μm – size of red blood cell)

• Contains **Nitrate and Sulfate** electron acceptors

• Treats BTEX, TPH-G, TPH-D, MTBE, naphthalene, etc.

• Easily injected with direct push using low pressure for uniform distribution

• Not recommended for free-phase LNAPL
Formulation

• +30% 1-2 μm carbon as shipped in 55-gallon poly drums
• Sulfate pre-blended in drum with carbon in form of calcium sulfate dihydrate = <10%
• Each drum of PetroFix also given:
  • 20 lb EA Blend, sulfate + nitrate (preferred)
    • 40 to 60% Ammonium Sulfate
    • 40 to 60% Sodium Nitrate
  • Or, 20 lb EA Blend NF, sulfate (nitrate free)
    • 40 to 60% Ammonium Sulfate
    • 40 to 60% Potassium Sulfate
Modes of Action

1. **Hydrocarbon Sorption**: Once injected, PetroFix coats soil surface with thin layer of carbon, then sorbs hydrocarbons.
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1. **Hydrocarbon Sorption**: Once injected, PetroFix coats soil surface with thin layer of carbon, then sorbs hydrocarbons.

2. **Stimulated Anaerobic Bioremediation**: Nitrate and sulfate kickstart bioremediation and enhance syntrophic remediation.
NO$_3^+$ + SO$_4^{2-}$ Promote Syntrophic Bioremediation

- Improved outcomes when NO$_3^+$ + SO$_4^{2-}$ used together – microbes “feed” together and have ecological partnership.
- Nitrate better for benzene. Sulfate reducers are versatile, co-exist with methanogens
- Fermentation of hydrocarbons, plus methanogenesis improved

Benefits of adding sulfate/nitrate continue after their exhaustion. 

Methanogenesis can finish the work:

Once Kickstarted, Methanogens can Finish the Job

Syntroph(s)

BTEX $\rightarrow$ COO$^-\rightarrow$ H$_2$ + acetate

TPH $\rightarrow$ COO$^-\rightarrow$ H$_2$ + acetate

characterized by higher redox potentials [8]. Some bacteria, such as sulfate-reducing Desulfovibrio spp., are metabolically versatile in that they respire sulfate when it is available, but switch to syntrophic metabolism in its absence [9*]. Other syntrophs are obligate in that they can
Colloidal Suspension Is “Flooded” vs “Fractured” =
Total Coverage of Migration Pathways and Excellent for Back Diffusion
### PetroFix Compared To Injectable Carbon

**Picture of Granular Activated Carbon (GAC)**
- Particle size: 400 to 1,000 microns
- **High Pressure** Needed (>60 psi)
- Results in Aquifer Fracturing? **YES**

**Picture of Powdered Activated Carbon (PAC)**
- Particle size: 50 to 250 microns
- **High Pressure** Needed (>60 psi)
- Results in Aquifer Fracturing? **YES**

**Picture of Liquid Carbon Suspension (PetroFix)**
- Particle size: 1 to 2 microns
- Low Pressure Needed (<60 psi)
- Results in Aquifer Fracturing? **NO**

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**Grain Size**

<table>
<thead>
<tr>
<th>Grain Size</th>
<th>Pore Throat Diameter (micrometers)*</th>
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<tbody>
<tr>
<td>Medium Sand</td>
<td>8-50</td>
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<tr>
<td>Fine Sand</td>
<td>5-20</td>
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<tr>
<td>Silt</td>
<td>3-8</td>
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*Note: Only LAC has a diameter below the typical pore throat diameter for silty soils.
Optimal Tooling To Inject PetroFix

- Top Down or Bottom Up Tooling Usually Recommended
- 2’ to 3’ vertical multi-port tooling work great in most aquifers and straddle inject product easily
- Helps keep pressures down and injection volumes up
Ease of Mixing PetroFix

Unlike bulk phase solids, suspensions like PetroFix can be pumped or poured into mix tank.

Water-like suspension like PetroFix requires only gentle agitation.
VERIFICATION OF PRODUCT PLACEMENT (observance in wells or soil cores)

PetroFix in wells can be flushed out using a clean-water flush. Instructions at www.petrofix.com
**Most Common Applications**

1. **Tank Removal/Upgrade**
   
   Excavation application addressing residual mass

2. **Contaminated Source Areas**
   
   - Grid Approach
   - Smear Zone

3. **Dilute Plume**
   
   - Use of Barriers
   - Eliminate off-site migration & reduce liability
Site 1: Panama City Beach, FL - BACKGROUND

- Former gasoline service station
- 1,000 Gal gasoline release 2007
- Excavation completed 2007 (~300 tons)
- Several remedial technologies have been implemented with limited success
- BTEX + Napth – 1,300 to 14,300 ug/l,
- TPHg 4,300-15,000 ug/l
Site 1: Panama City Beach, FL

- 1,700 lbs of PetroFix injected w/ sulfate + nitrate EA Blend
- 10 direct push points, 20’x20’ test area
- Target zone: 5-15’ bgs
- Homogenous beach sand
- Excellent distribution across target treatment zone
- Confirmed 5-6 ft spacing was optimal
Site 1: Panama City Beach, FL - RESULTS

- Groundwater Concentrations ND by first monitoring event and through April 2019.
- FULL SCALE PLANNED FOR FALL 2019
Site 2: Northern IN - BACKGROUND

- Historical Bulk Petroleum Storage Facility
- LNAPL Recovery – 2006,
- AS/SVE – 2007-2009
- BTEX – 3,500 ug/l
- TPH-G – 38,800 ug/l
- TPH-D – 17,800 ug/l
Site 2: Northern IN

- 2,000 lbs of PetroFix injected with sulfate + nitrate EA Blend
- 12 direct push points
- Target treatment zone: 15-22’ bgs
- Heterogeneous soils
- 5-7’ spacing optimal
Site 2: Northern IN – Results for Gas and Diesel

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<tbody>
<tr>
<td>TPH-GRO (μg/L)</td>
<td>33,800</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,170</td>
<td>506</td>
<td>0</td>
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<tr>
<td>TPH-DRO (μg/L)</td>
<td>17,800</td>
<td>3,600</td>
<td>4,200</td>
<td>250</td>
<td>596</td>
<td>538</td>
<td>1680</td>
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Site 2: Northern IN – Results for BTEX

- Client suspected some rebound. Beta in center of plume and being recharged with upgradient contamination
- 94.5% reduction to date
- Full-Scale initiated upgradient in March-April 2019

### Analyte Results

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<tbody>
<tr>
<td>Benzene</td>
<td>149</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>69.9</td>
<td>36.8</td>
<td>3.04</td>
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<td>Toluene</td>
<td>191</td>
<td>0</td>
<td>5.7</td>
<td>0</td>
<td>139</td>
<td>68.2</td>
<td>2.05</td>
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<tr>
<td>Ethylbenzene</td>
<td>330</td>
<td>0</td>
<td>5.6</td>
<td>14</td>
<td>49.1</td>
<td>19.2</td>
<td>0</td>
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<tr>
<td>Xylenes</td>
<td>2,610</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>181</td>
<td>56.6</td>
<td>0</td>
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Lines of Evidence for biodegradation

1. Electron Acceptors Deplete over time
   • Nitrate consumption > sulfate
2. Products of reaction
   • Sustained methane production (from hydrocarbon biodegradation) lasting after nitrate, sulfate consumed
   • Contaminants bioavailable
   • Attributed to syntrophic biodegradation
1. Regenesis evaluates your data and co-develops remedial conceptual model based on goals

2. Regenesis selects a technology

3. Regenesis provides a remedial design (1 to 2 weeks)

4. Optional – Regenesis Remediation Services bids and injects for you
NEW PETROFIX DESIGN – ONLINE DESIGN ASSISTANT PROVIDES DESIGN, WE SUPPORT

1. You evaluate your data and enter values based on your remedial conceptual model and goals

2. Use PetroFix Design Assistant and obtain design and useful output (<20 minutes)

3. PetroFix Design Assistant flags if you need something more aggressive – engage with Regenesis as needed

4. You bid and hire injection contractor using output from PetroFix Design Assistant and website resources
PETROFIX DESIGN ASSISTANT

✓ YouTube Training Video Available (9m 19s)
✓ Rapid designs provides dosage, volume and spacing and other variables
✓ Send output to local driller for bid
✓ www.petrofix.com/design
Self-Design and Application - Calculations

- Calculate treatment volume and effective porosity based on soil type
- Use PetroFix isotherms to calculate loading rate for dissolved mass.
- Estimated sorbed mass with text book values of Koc and Foc for contaminants and soil type
- Estimate dilution factors
- Estimate spacing based on soil type
- Round to nearest drum
PETROFIX INJECTION INSTRUCTIONS

PetroFix Application Instructional YouTube Training Video Available (4m 23s)

✓ Find under “You Apply”
✓ Installation equipment required
✓ Tools and supplies required
✓ Mixing and injection instructions
✓ Documenting distribution
Thank you!

For More Information Go To:
www.petrofix.com

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