The InSitu Remediation of PFAS-Impacted Groundwater Using Colloidal Activated Carbon

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InSitu Remediation Services

RemTech 2018
Background

• Per & Polyfluoroalkyl Substances (PFAS)
• Emerging Compounds of Concern
  • Perfluorooctane Sulfonate (PFOS)
  • Perfluorooctanoic acid (PFOA)
• Thousands of compounds
• Shown to bioaccumulate
• Analytical challenges
• Health Advisory Levels 10s of ng/L (ppt)
• Fate & transport not well understood
  • A. Weber et al. (ES&T, 2017)
  • Anderson et al. (Chemosphere, 2016)
  • Xiao et al. (Water Research, 2015)
Background

• Perfluorinated Compounds
  • 6 million Americans exposed

• Reagents for aqueous film forming foam (AFFF)

• Coating Agents

• Repellants for fabrics

U.S. EPA
Background

• InSitu Treatment
  • Limited demonstrated options
  • Resistant to chemical oxidation due to C-F bond
  • Low remedial concentrations required
  • Sensitive to back & matrix diffusion

• Lab or Pilot Approaches
  • Chemox
  • Nano Pd/ZVI
  • Activated Persulfate
  • B12
  • Activated Carbon

Park et al., 2015
Background

- **Activated Carbon**
  - Well demonstrated for above ground treatment
  - Limited data on insitu performance
- Fate & transport not well understood
- Injectability
- Distribution
- Lifespan
  - Capacity differs for various PFAS
  - Competition for sites
  - Destruction vs unavailability
- Back diffusion

Source: Xiao et al., 2017
Background

- Particle Size
  - In general the smaller the particle size the greater the capacity

Source: Xiao et al., 2017
Study Site

• Petroleum Hydrocarbon Spill
  • Source excavated
  • Residue PHCs in soil and groundwater
    • BTEX < 300 ug/L
    • F1 < 2,000 ug/L
    • F2 < 3,500 ug/L
  • Mention of site being used as a fire fighting training site and old building used for fabric coating
  • Grabbed groundwater samples for PFOA and PFOS analyses
  • Detected!
    • PFOS up to 1,450 ng/L
    • PFOA up to 3,260 ng/L
Study Site

- PFOS
- PFOA

Suspected Source Area

Groundwater Flow
Study Site

Geology
- Glacial-fluvial deposit
- Sand to silty sand
- Sand lens (less than 0.02 metres thick)

Hydrogeology
- Shallow water table (~1 mbgs)
- Unconfined
- $K \sim 2.6 \text{ m/day}$
- $i \sim 0.06$
- $V \sim 0.8 \text{ m/day}$
- Effective porosity $\sim 0.2$
Study Site

Geochemistry

- Carbonate-bearing aquifer
  - Alkalinity ~270-400 mg/L as CaCO3
- Reducing
  - Nitrate and oxygen depleted
  - Iron-sulfate reducing
- High chloride concentration
  - ~180 mg/L Cl
  - ~140 mg/L Na

Source

- Excavated
- Calculated mass flux of ~1.8 g/year (G. Carey)

Courtesy: G. Carey
Remedial Review

- Why liquid activated carbon?
  - ~30 sites in Canada
  - Excellent injection “properties”
    - Viscosity and density of water
    - Colloidal (1-2 microns)
    - Surface area ~5,500 m²
  - Potentially quick
    - One time application
    - Less disruption
- Cost
  - ~$75,000 CDN
Injection Methodology

- Based on Pore Volume
  - One event
- Direct Push
- Geology Specific Tools
- Multiple Locations
- Multiple Intervals
- Low Pressure
  - <25 psi
- Low Volume
  - ~100 to 200 litres/location
Injection Methodology

- Both Plumes - combination of adsorption-aerobic bio
  - 725 kg of concentrated liquid activated carbon
  - 440 kg of oxygen-releasing material
  - 7,800 litres of water
  - 50 locations

Courtesy: G. Carey
Injection Methodology

- PFAS Plume - combination of adsorption-aerobic bio
  - 290 kg of concentrated liquid activated carbon
  - 176 kg of oxygen-releasing material
  - 3,120 litres of water
  - 20 locations

Courtesy: G. Carey
Results

Evaluation Criteria

• Budget
  • Timing and Budget

• Distribution
  • Target Zone
  • Area of Influence

• Short term results
  • Up to 1 year

• Long term results
  • Post 1 year
Results

• Budget
  • 50 locations
  • 3 days
    • On time
• Minimal daylighting
  • Injection ~ 0.8 m below grade
  • Less than 8 litres of solution total
• Budget
  • $75,000 CDN (~$60,000 US)
  • On budget
Results

Distribution

- Observation in wells during injection
- Cores
  - Radius of influence
  - Target zone
  - Overall coverage

ROI Cores

Coverage Cores
Results

Distribution

• Overall Coverage
Results

Distribution

• Radius of Influence

Injection Pt
Background

SEM Photography Sand Grain

SEM Photography Sand Grain with PlumeStop

Courtesy: Regenesis
Results

Short and Long Term Chemistry

• PFOS & PFOA
  • 3 months
  • 6 months
  • 9 months
  • 12 months
  • 18 months
  • 21 months

• Other PFAS Compounds
  • 18 & 21 months
  • PFBS, PFHxS, PFDS, PFOSA, PFBA, PFPeA, PFHxA, PFHpA, PFNA, PFDA, PFUnA & PFDa

• Detailed Inorganic Parameters
  • 18 months

• Next Generation Sequencing
  • 18 months
Results

• Short Term Results
  • BTEX and PHC results
    • 3 months
      • Non Detect for BTEX, F1 & F2
    • 12 months
      • Detections for BTEX and F1 but well below the Standards

• PFOS and PFOA
  • 3, 6, 9 & 12 months
    • Non Detect

Source: G. Carey, 2017
Results - One Year

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</tbody>
</table>

Courtesy: J. Birnstingl
Results

Long Term Results

- **BTEX and PHC results**
  - 18 & 21 months
  - Detections for BTEX and F1 but well below the Standards

- **PFOS and PFOA**
  - 18 & 21 months
  - PFOA - ND
  - PFOS - 40 ng/L (18 months)

- **Other PFAS**
  - All ND except PFUnA
  - 20 ng/L (18 months)
Preliminary Conclusions

- Liquid activated carbon
  - Effective over the short term for removal of PFOS, PFOA and other PFAS
  - Adsorbed, not destroyed
- Long term monitoring required for:
  - Partitioning
    - Does it stay on LAC?
    - Modelling (Dr Carey) of longterm behaviour
  - Biodegradation PFAS on/near LAC
    - Does it degrade?
PFAS Remediation Research Group

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