THE HORIZONTAL REACTIVE MEDIA TREATMENT WELL (HRX WELL™) – DEMONSTRATION OF A NEW TECHNOLOGY FOR PASSIVE IN-SITU REMEDIATION

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HRX Well Description

The HRX Well (Patent US8596351B2) is a large-diameter horizontal well installed along the groundwater flowpath that is filled with reactive media.

- Passive in-situ treatment
- Many solid-phase reactive media options
- Efficient use of reactive media
- Not limited to high-permeability aquifers
- Can be applied in relatively deep settings
- Limited above-ground footprint
- No ongoing energy or O&M requirements
- Pumping can enhance treatment zone
### Potential Reactive Media and Contaminants

<table>
<thead>
<tr>
<th>Reactive Media</th>
<th>Target Groundwater Contaminant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero valent iron (ZVI)</td>
<td>Chlorinated solvents (CVOCs), nitrate, perchlorate, energetics, chromium, arsenic, other metals</td>
</tr>
<tr>
<td>Bimetallics (e.g., ZVI + Pd, Pt, or Ni)</td>
<td></td>
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<tr>
<td>Granulated Activated Carbon (GAC)</td>
<td>CVOCs, PFAS, hydrocarbons, Halomethanes</td>
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<tr>
<td>Ion exchange resins</td>
<td>Brines</td>
</tr>
<tr>
<td>Biodegradable particulate organic carbon (e.g., mulch)</td>
<td>CVOCs, nitrate, perchlorate</td>
</tr>
<tr>
<td>Phosphates (e.g., apatite)</td>
<td>Lead, uranium, other metals and radionuclides</td>
</tr>
<tr>
<td>Sustained Release Oxidants (e.g., RemOxSR+ISCO)</td>
<td>CVOCs, 1,4-dioxane, hydrocarbons, polyaromatic hydrocarbons (PAHs), phenolic compounds, and energetics</td>
</tr>
<tr>
<td>Limestone, lime, magnesium oxide</td>
<td>Low pH, Acid Rock Drainage</td>
</tr>
<tr>
<td>Barium sulfate (barite)</td>
<td>Radium</td>
</tr>
<tr>
<td>Iron sulfide</td>
<td>Cr, High pH</td>
</tr>
<tr>
<td>Zeolites</td>
<td>Ammonium, radionuclides</td>
</tr>
</tbody>
</table>
Treatment Width

\[ W_{\text{treatment}} = \frac{Q_w}{T_A i_A} \]

\[ Q_w = K_w A_w i_w \]

- \( W_{\text{treatment}} \): HRX treatment width
- \( Q_w \): Flow in HRX well
- \( T_A \): Aquifer Transmissivity
- \( i_A \): Aquifer hydraulic gradient
- \( A_w \): x-sectional area of HRX well
- \( i_w \): Hydraulic gradient in HRX well

For passive configurations, treatment widths of 50+ feet are feasible.
Modeling

- 300 ft long, 20 ft deep, 1 ft diameter,
- Homogeneous aquifer, $K_A=2.8$ ft/day, $K_W=2,800$ ft/day
- Treatment width = ~45 ft.
Objectives (ESTCP ER-201631)

1. Full-Scale demonstration of technology to control mass discharge
2. Measure the actual performance and compare to model predictions.
3. Assess actual implementability, cost and sustainability performance
4. Develop a user tool and guidance for conceptual design and costing.
ZVI Selection and PVP Design

- No progressive losses in $k$ over time (>1000 pore volumes in these tests)
- Connelly iron selected based on best overall performance
- Modified laboratory PVP accurately and measured seepage velocities
Tank Testing

- Validated HRX Well hydraulics
- Validated contaminant treatment with GAC and ZVI
- HRX Well ZVI performance sustained over 100+ Pore Volumes
Pilot Scale Testing

- HRX Well captured 39% of flow while representing 0.5% of test pit volume
- Verified hydraulic and reactive transport model
- Further tracer testing currently underway
Field Demonstration

Site SS003, Vandenberg Air Force Base

- Objective: significantly reduce mass discharge from the source
- $K = 1\text{–}10$ ft/day, thickness 5\text{-}10 ft, depth ~20 ft, low ambient gw flux
Field HRX Well Design

- Length: 550 ft; Depth: 20 ft; Diameter: 12-in; Reactive media: 35% ZVI (60 ft)
- Target treatment width: 56 ft, Residence time: 6-8 days
- 2 PVPs, samples, tracer testing to measure in-well velocity, flux, concentrations
Monitoring and ZVI Cartridge Designs

Monitoring cartridge (5 ft)

ZVI cartridge (10-ft)
Design Model Results

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Field Installation (July/August 2018)
## Alternatives Analysis

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Alternative #1 HRX Well</th>
<th>Alternative #2 Groundwater Extraction and Treatment System</th>
<th>Alternative #3 Funnel and Gate PRB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall protection of human health and environment</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Effectiveness and permanence</td>
<td>Moderate to High</td>
<td>Moderate</td>
<td>Moderate to High</td>
</tr>
<tr>
<td>Reductions in toxicity, mobility, and volume through treatment</td>
<td>Moderate to High</td>
<td>Moderate</td>
<td>Moderate to High</td>
</tr>
<tr>
<td>Implementability</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Sustainability</td>
<td>High</td>
<td>Low to Moderate</td>
<td>Moderate to High</td>
</tr>
<tr>
<td>Lifecycle Cost*</td>
<td>Low to Moderate</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>$2.4-3.1M</td>
<td>$3.8-4.7M</td>
<td>$3.6-4.5M</td>
</tr>
</tbody>
</table>

*Full-scale costs assume a target treatment width of 150 ft
Closing

Future Performance Monitoring
- Groundwater monitoring
- Point Velocity Probes (PVPs)
- Tracer Testing

The HRX Well offers the following advantages
- In situ mass flux control
- Passive operation or enhanced capture zone with pumps
- Many reactive media options and therefore applicable to many contaminants
- Efficient media usage, easy change-out, can use multiple types
- Limited above-ground footprint
- No ongoing energy, water, or O&M requirements
- Favorable lifecycle cost comparison to P&T and PRB
Thank You

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Divine et al., 2018. The Horizontal Reactive Media Treatment Well (HRX Well®) for Passive In-Situ Remediation. Remediation, DOI: 10.1002/rem.21571

Divine et al., 2018. The Horizontal Reactive Media Treatment Well (HRX Well®) for Passive In-Situ Remediation. GWMR, DOI: 10.1111/gwmr.12252