Delivery Tools for Combined Remedies

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Why Injection Isn’t for Amateurs
BEFORE

AFTER
If you can set up your next shot, you are more likely to WIN!!!

ISCO vs ISCR

- Oxygen vs Hydrogen (and sometimes sulfide)
- For ISCO, persulfate, permanganate, peroxide, ozone, etc.
- Oxygen for biological processes
- For ISCR, zero valent iron (ZVI), polysulfide
- Carbon substrates (and maybe sulfate) fermenting to hydrogen
TOTAL OXIDANT DEMAND

No Matter How well the amendment is delivered, if the chemistry isn’t correct, the treatment will fail

Total Oxidant Demand can vary between <0.1 to 155 g/Kg

Delivery Options

• Geoprobe Injection
• Fixed Wells
• Infiltration Galleries
• Hydraulic Fracturing
• Pneumatic Fracturing
• Dry Media Injection
• Mechanical Mixing
Geoprobe Injection

Geoprobe Advantages

- Lowest initial cost
- Flexibility to adapt injection strategy
- Can target multiple discrete intervals
- “Bottom-Up” or “Top Down” injection
- No well permits required in many States
- Widely available
- No precipitate fouling & can inject solids
Geoprobe Disadvantages

- Additional injections will require another geoprobe mobilization
- Greater potential for leaking along the casing vs. fixed wells
- Materials compatibility with Geoprobe rods
- Geoprobe injection points can be conduits for other injection points
- Clogging of geoprobe rods with flowing sands
- May get an operator not experienced with handling chemicals

Fixed Wells - Advantages

- Not paying for Geoprobe when not being used
- Can be used multiple times
- Wide variety of well materials available
- No problems with flowing sands (after installation)
Fixed Wells - Disadvantages

• If the well “fails”, you are “stuck”
• May have particulate fouling
• More difficult to isolate targeted interval – packers time-intensive
• Can’t perform fracturing through wells screens

Horizontal Wells

• Access difficult areas, under buildings, roads, etc.
• Long continuous screens perpendicular to flow
• Costs have steadily decreased over time
• Requires more careful consideration of fluid dynamics because injection pressure decreases over the length of the well
INFILTRATION GALLERIES

• Provide a linear discharge of amendments
• Difficult to control delivery rates because typically done under gravity
• Caution that amendments or changing geochemical conditions can lead to plugging

Hydraulic Fracturing

• Injection of water, solution or slurry at pressure that exceeds the lithostatic pressure and cohesive strength of the formation
• Results in short-term enhancement of soil permeability
• With proppant, long-term enhancement is achieved
• Increases radius-of-influence and injection rate
Hydraulic Fracturing

Secondary Delivery

- Carbon Substrate
- ZVI
- Hydrogen peroxide
- Calcium Peroxide
Pneumatic Fracturing

• Injection of gas at pressure that exceeds the lithostatic pressure and cohesive strength
• Results in short-term enhancement of soil permeability
• With proppant, long-term enhancement is achieved
• Increases radius-of-influence
• Larger volume of fluid than hydraulic

Soil Blending

• Efficient and uniform delivery of remediation amendments
• Production rates comparable to dig, haul and backfill
• No long term liability associated with disposal
• Costs can be 2 to 10 times less expensive than dig and haul, depending upon the extent of contamination
• No RCRA TSD permits are required
• Greener solution that results in treatment not transfer
When to Consider Using Soil Blending

- Cohesive or low permeable soils
- High volumes of amendment
- Timeframe for cleanup is short
- Shallow water table
- High disposal costs

Deep Soil Augers/Mixers

- Great for deep applications at well characterized sites
- Not as efficient for large areas.
- High Mobe/demobe costs

Source: www.haywardbaker.com
Excavator Style Soil Blenders

- **Soil Blenders** are limited in depth (~ 25’) without benching but:
  - Can efficiently blend large areas
  - Production rates 200 to 600 tons per day
  - Fit on standard size equipment so smaller equipment footprint
  - Lower mob/demob costs

Soil Blenders

<table>
<thead>
<tr>
<th>ALLU</th>
<th>REDOX - LANG</th>
<th>REDOX TECH</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMX-500</td>
<td>Modified Lang</td>
<td>Redox Tech Custom</td>
</tr>
<tr>
<td>Constant Power: 90 HP</td>
<td>Constant Power: 200 HP</td>
<td>Constant Power: 295 HP</td>
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<tr>
<td>Dual Motors: Yes</td>
<td>Dual Motors: No</td>
<td>Dual Motors: Yes</td>
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<tr>
<td>Automatic Power Control: No</td>
<td>Automatic Power Control: No</td>
<td>Automatic Power Control: Yes</td>
</tr>
<tr>
<td>Reach Working Depth in Clay: No</td>
<td>Reach Depth in Clay: Sometimes</td>
<td>Reach Working Depth in Clay: Yes</td>
</tr>
<tr>
<td>Blend Weathered Rock: No</td>
<td>Blend Weathered Rock: Maybe</td>
<td>Blend Weathered Rock: Yes</td>
</tr>
</tbody>
</table>
Stabilization

- Commonly cited shortcoming is that soil blending lowers cohesive strength and loading rates
- However, Portland cement, lime, or fly ash can be blended to improve soil geotechnical properties
- Also, stabilization can be an effective method for in place treatment (activated carbon often added)
- Typical cost is about $5-10 per yard

Case Study

- Former manufacturing facility in NC
- Treated an area of ~2800 sq ft from 4 to 24 ft bgs
- Potassium permanganate applied at a loading rate of 5 g/kg (3,100 tons) to treat Vinyl Chloride concentrations of <100ppb in soil
- Post blending samples all Non-Detect (<5ppb in soil)
- Site required immediate stabilization to allow vehicle traffic
- Applied 60,000lbs of Portland cement to upper 5 feet of soils
Adding 3 wt% Portland

Blending Portland
Case Study No. 1  
Sodium Persulfate and Heat  
Plymouth, New Hampshire  

- Active convenience store and gas station.  
- Three underground storage tanks (5,000 to 8,000 gallons) located approximately 40 feet northeast of treatment area.  
- Gasoline release was detected in early 90’s and between 1994 and 1998 a pump and treat and SVE system was operating to remove product. System shut down in 1998.  
- Passive recovery was conducted in the early 2000’s. Only recovered 4 gallons.  
- MW-13 has product from sheen to 0.4 feet. Recovery wells are located near monitoring well.

Treatment Area (~ 2,500 SF)
Injection Plan

- 2,500 Square Feet.
- Four black iron injection points installed in area of MW-13 and RW-2. Five direct push points for dissolved plume.
- 8,500 pounds of sodium persulfate was injected into all 9 injection points. This was done first.
- Injection points received 450 gallons of a 25 wt% sodium persulfate solution.
- Two steamers injected heated water (low flow) to raise temperature to 40°C following persulfate injection.

Results

- MW-13: ND for product thickness; 4,000 ppb of total VOCs. Product not detected in surrounding wells.
- Dissolved plume: 84% reduction to no change.
- Second injection with Oxygen BioChem (OBC) and there was 50% to 90% reduction.
- Nine wells are below standards and seven have been decommissioned (2015 report to NH).
- Project was completed in 2010/2011.