"Soil and Groundwater Remediation is our art"

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Technology Overview

- Integrated, synergistic technology suite
- Contaminated soil and groundwater
- Minimal site impact
- Expedite site closure
- Utilizes proven technologies
Introducing

ART Integrated Remediation System

- In-well Air Stripping
- In-Well Air Sparging
- Soil Vapor Extraction
- Bioremediation/Oxidation
- Dynamic Subsurface Circulation™
- Plus, UV & Ozone Injection

proprietary - patented
Sparging

Groundwater level from sparging and vacuum

Effects

Cleaner, low density water

Vault

Amendments

Dynamic Subsurface Circulation™

Air Stripping/Hydraulic Delivery

Soil Vapor Extraction

Amendments

Grade

Negative Gradient

Pump

Soil Vapor Extraction

Air Stripping/Hydraulic Delivery

Cleaner, low density water

Dynamic Subsurface Circulation™

Soil Vapor Extraction

Groundwater level from sparging and vacuum

Groundwater level from sparging

Negative Gradient

Amendments

Cleaner, low density water

Vault

Sparging

Amendments

Effects
MTBE/BTEX/TPH Case History

Site Location: Gardena, California

Contaminants: BTEX/TPH/MTBE

Site History: Former gas station, now major retail chain store

Soil types: silty to clayey sand with sandy silt and sandy clay layers

Groundwater: 25 feet bgs

Remediation History: Dual phase SVE/sparge/pump and treat installed in 1998

Client Goals: Jump start stalled remediation
### 90 Day Demo Results

<table>
<thead>
<tr>
<th>Gardena, CA</th>
<th>Sampling Round</th>
<th>TPHg (µg/l)</th>
<th>Benzene (µg/l)</th>
<th>Toluene (µg/l)</th>
<th>Ethyl benzene (µg/l)</th>
<th>Xylene (µg/l)</th>
<th>MTBE (µg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery Well Source Area</td>
<td>Baseline</td>
<td>18,000</td>
<td>3,300</td>
<td>1,100</td>
<td>610</td>
<td>2,400</td>
<td>1,100</td>
</tr>
<tr>
<td>MW-L 25’ downgradient</td>
<td>Baseline</td>
<td>8,000</td>
<td>880</td>
<td>35</td>
<td>95</td>
<td>430</td>
<td>970</td>
</tr>
<tr>
<td></td>
<td>14 days</td>
<td>14,000</td>
<td>2,600</td>
<td>59</td>
<td>510</td>
<td>1,400</td>
<td>1,500</td>
</tr>
<tr>
<td></td>
<td>33 days</td>
<td>1,800</td>
<td>440</td>
<td>2.9</td>
<td>51</td>
<td>47</td>
<td>460</td>
</tr>
<tr>
<td></td>
<td>84 days</td>
<td>290</td>
<td>64</td>
<td>0.8</td>
<td>5.2</td>
<td>3.6</td>
<td>200</td>
</tr>
</tbody>
</table>

Average mass removal over the time period was approx. 12.5 lbs/day.
**MTBE/BTEX/TPH Site Closure**

**Site Location:** Isleton, California

**Contaminants:** Gasoline, Diesel, MTBE

**Site History:** Tanker spill (750 gallons), downgradient receptors

**Soil types:** Sands, silts

**Groundwater:** Fluctuating 10-15 feet bgs

**Client Goals:** Quick response, fast remediation, protect drinking water wells
## MTBE Remediation Summary

<table>
<thead>
<tr>
<th>Month/Year</th>
<th>9/02</th>
<th>12/02</th>
<th>3/03</th>
<th>4/03</th>
<th>6/03</th>
<th>7/03</th>
<th>8/03</th>
<th>10/03</th>
<th>2/04</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTBE (µg/l)</td>
<td>42,000</td>
<td>4,800</td>
<td>150</td>
<td>780</td>
<td>32</td>
<td>26</td>
<td>9.1</td>
<td>5.7</td>
<td>2.8</td>
</tr>
</tbody>
</table>

**Cleanup Std. 13 ppb**

- Reduced MTBE to below primary, secondary cleanup standards
- ART system shut down in August 2003
- Sampling to identify rebound
- Testing confirmed no rebound
- Concentrations continued to decrease
- **Well pulled, closure letter received**
New Jersey BTEX Demo

- **Site Location**: New Jersey
- **Contaminants**: BTEX
- **Site Description**: Shallow groundwater – silty, non-homogeneous sand formation
- **Remediation History**: 6 years of Air Sparging / SVE; Levels reached asymptote
- **Corrective Action**: Retrofitted ART Technology to existing blower, compressor, and off-gas treatment; 2 ART wells installed in Sept. 04
## ART Remediation Results

<table>
<thead>
<tr>
<th>Elapsed</th>
<th>MW-1</th>
<th>MW-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>B</td>
<td>T</td>
</tr>
<tr>
<td>0</td>
<td>2,650</td>
<td>11,000</td>
</tr>
<tr>
<td>28 days</td>
<td>2</td>
<td>62</td>
</tr>
<tr>
<td>78 days</td>
<td>15</td>
<td>61</td>
</tr>
<tr>
<td>% Reduction</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

**78 Days ➔ Average 98% Contaminant Reduction**
Site Remediation History

- **May 2002:** On-Site Soil & Groundwater Remediation Using Magnesium-Based Peroxygender Injections.
- **May 2004:** Corrective Action Plan Submitted to Jump Start On-Site Soil & Groundwater Remediation.
- **December 2004:** CAP Approved by Illinois EPA as a Pilot Study Using 1 ART Well.
Groundwater Data Using Peroxygent Injections in 2002

- **Source Area (MW-11):** increase of 55% benzene and 10.2% BTEX.
Groundwater Data Using ART Technology

- **OW-1** (10 ft from ART): reduction of 99.0% benzene and 98.7% BTEX
- **OW-2** (20 ft from ART): reduction of 99.3% benzene and 89.9% BTEX
- **MW-11** (30 ft from ART): reduction of 99.3% benzene and 89.8% BTEX
- **OW-3** (40 ft from ART): reduction of 96.5% benzene and 87.5% BTEX
- **MW-3** (down-gradient property line): reduction of 21.8% benzene and 60.2% BTEX
Benzene Exceedance in Soil

Prior to Remediation

<table>
<thead>
<tr>
<th>Location</th>
<th>Depth</th>
<th>Benzene (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB-1</td>
<td>10.5' bgs</td>
<td>0.231</td>
</tr>
<tr>
<td>PB-2</td>
<td>8.5' bgs</td>
<td>0.231</td>
</tr>
<tr>
<td>SB-8</td>
<td>3-5' bgs</td>
<td>0.182</td>
</tr>
<tr>
<td>PB-4</td>
<td>10' bgs</td>
<td>0.986</td>
</tr>
<tr>
<td>SB-16</td>
<td>5-7' bgs</td>
<td>0.156</td>
</tr>
<tr>
<td>PB-10</td>
<td>4' bgs</td>
<td>0.257</td>
</tr>
<tr>
<td>PB-11</td>
<td>7.5' bgs</td>
<td>0.219</td>
</tr>
<tr>
<td>PB-12</td>
<td>8' bgs</td>
<td>1.33</td>
</tr>
<tr>
<td>PB-13</td>
<td>4' bgs</td>
<td>0.17</td>
</tr>
<tr>
<td>SB-15</td>
<td>3-5' bgs</td>
<td>0.148</td>
</tr>
</tbody>
</table>

Benzene 0.03 mg/kg
Benzene Exceedance in Soil
As of October 23, 2007

<table>
<thead>
<tr>
<th>Location</th>
<th>Depth (bgs)</th>
<th>Benzene (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS-1 (PB-1)</td>
<td>10.5</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>CS-2 (PB-2)</td>
<td>8.5</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>CS-3 (PB-10)</td>
<td>4</td>
<td>0.0293</td>
</tr>
<tr>
<td>CS-4 (PB-11)</td>
<td>7.5</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>CS-5 (SB-16)</td>
<td>5-7</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>CS-6 (PB-13)</td>
<td>3.5</td>
<td>0.0392</td>
</tr>
<tr>
<td>CS-7 (PB-12)</td>
<td>8</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>CS-8 (PB-11)</td>
<td>7.5</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>CS-9 (PB-12)</td>
<td>4</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>CS-10 (SB-15)</td>
<td>3-5</td>
<td>0.0205</td>
</tr>
</tbody>
</table>

0.03 mg/kg
Benzene in Groundwater Prior to Remediation (May 15, 1996)

Benzene 0.005 mg/L
Benzene in Groundwater (January 9, 2008)

ART System
Running 261 Days

Benzene 0.005 mg/L
Remedial Goals

**Project Objectives**

1. Remediate Benzene Soils to <0.03 mg/kg
2. Remediate Benzene Groundwater to <0.005 mg/L
3. Accelerate Remediation Time with Minimal Cost
4. Reimbursement from the Illinois LUST Fund

**Accomplishments**

- 99% Complete
- 95% Complete
- Yes (97% Complete in 261 Days)
- Yes
Potential Remedy Configuration

ART Well

Groundwater Flow

ART Source Control

ART Flow Through Treatment

ART Well
**PCE Case History**

- **Site Location:** Colorado
- **Contaminants:** tetrachloroethene (PCE) – 4 mile plume impacting surface water/drinking water wells
- **Site History:** Industrial manufacturing facility
- **Soil Types:** fine, silty, heterogeneous sand; steep gradient
- **Groundwater:** 3 ft saturated thickness; paleo channels
- **Regulatory agency:** State of Colorado
  - Significant regulatory scrutiny – lawsuits pending
- **Client’s Goals:** pilot test numerous “new” technologies and select remedy
**Demo Results**

- Significant reduction in PERC/7 weeks
- Outperformed: SVE, P&T, AS, Anaerobic Degradation Compound injection
- “Radius of Influence” about 50 feet
- Pleased clients/consultants

**Current Site Wide Status**

- Phase II: 15 additional ART wells installed
  - Source control – two areas
  - Downgradient flow through treatment cell(s)
- 85% reduction in contamination leaving source area in first 6 months operation
PCE Frac Bedrock Site Closure

- **Site location:** Allentown, PA
- **Contaminants:** PCE at 403 ppb
- **Site History:** Industrial *dry cleaning* facility
- **Soil type:** Silty clay underlain by dolomite
- **Groundwater:** GW at 90 feet, secondary porosity in fractured bedrock
- **Regulatory agency:** PA DEP
- **Client’s Goals:** Retrofit wells to ART Tech
PCE Fractured Bedrock

Latest Results @ ND

PCE Concentrations

Months

Feb 2002

Nov 2004

Action Level

Micrograms/liter

0

500

400

300

200

100

0
**Final Results**

- “Radius of Influence” at least 40 feet in fractured bedrock
- Proves significant reduction of lower levels in very challenging setting
- Reduction in PERC to below Action Level in less than 9 months
- Reached ND within two years
- Received letter of closure from PADEP
1,4 Dioxane Case History

- 1,4 dioxane and VOC impacted site
- Bedrock overlain by saprolitic soils
- Levels reached asymptote
- Numerous technologies screened
- ART demonstration project
- Selection based on past recalcitrant/VOC performance history
# 1,4 Dioxane Demo Results

<table>
<thead>
<tr>
<th></th>
<th>MW-1</th>
<th>MW-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial concentrations (µg/L)</td>
<td>25,000</td>
<td>28,000</td>
</tr>
<tr>
<td>90 days later (µg/L)</td>
<td>7,400</td>
<td>2,400</td>
</tr>
<tr>
<td>Percent reduction</td>
<td>76%</td>
<td>91%</td>
</tr>
</tbody>
</table>

- 1,4 Dioxane vapor concentrations exceeded 1.1 PPMV
- 2.25 pounds removed
Once through stripping of 1,4 Dioxane

100 ppm

Based on:
30% Air stripping efficiency of 1,4 dioxane

Not acceptable!

70 ppm
ART Removal Rate

Approximate ART Efficiency
30% Air stripping
20% In-well sparging
50% Total

9 In-well stripping passes
>99% removal
Sparging

Groundwater level from sparging and vacuum

Cleaner, low density water

Soil Vapor Extraction

Amendments

Effects

Vault

Pump

Negative Gradient

Grade

Amendments

Cleaner, low density water

Groundwater level from sparging and vacuum

Groundwater level from sparging

Negative Gradient

Negative Gradient
**AS/SVE vs. ART - Total VOC**

<table>
<thead>
<tr>
<th>System</th>
<th>1,1,1-TCA</th>
<th>1,1-DCA</th>
<th>1,1-DCE</th>
<th>PCE</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS/SVE</td>
<td>0.06</td>
<td>0.07</td>
<td>0.06</td>
<td>0</td>
<td>0.19</td>
</tr>
<tr>
<td>ART Well</td>
<td>8.06</td>
<td>0.37</td>
<td>0.58</td>
<td>0.38</td>
<td>9.39</td>
</tr>
</tbody>
</table>

- **ART system** (one well) outperformed the **AS/SVE system** (six AS and nine SVE wells operating since ‘94).
Technology Advantages

- Synergistic technologies, effects
- No surface discharge, fees, disposal, permits
- Utilizes common 4” or 6” wells
- Enhances bioremediation/oxidation
- Retrofit to new OR existing systems
- Proven technical concepts
- Immediate Results
Limitations

Hydraulic conductivity $> 10^5$ cm/sec.
Check Valve - water in
The Question Is...

Why rely on only one... when you *can* install more than six technologies for the same cost!?