Design and assessment of electrochemical zones for remediation of chlorinated solvents in natural groundwater aquifer settings

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Design and assessment of electrochemical zones for remediation of chlorinated solvents in natural groundwater aquifer settings

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I Project objectives

- Optimization of electrochemical zone(s) for complete degradation of the harmful chlorinated solvents and their chlorinated degradation products in natural hydrogeological settings as a precautionary measure

II Motivation

- Chlorinated solvents threaten the quality of groundwater and cause health risks [1]. Consequently, extraction wells for drinking water are closed
- The compounds’ properties challenge the current treatment systems
- Commonly used pump-and-treat systems for hydraulic containment are long-term solutions with substantial operation and maintenance costs
- Optimized means of protecting the groundwater from these contaminants are requested. We propose, establishment of electrochemical zones for in situ degradation of chlorinated solvents and degradation products.

III Relevant chemical processes

- Reactants can be generated and subsequently reduce or oxidize the chlorinated solvents [3] and fast electrochemical reduction of chlorinated solvents near the electrodes can be obtained [2].

IV State of the art

- Focus has been on the influence from electrode materials [6,7,9] and configurations [7,8], and of system parameters such as current density [6,7,8,9,10], flow rate [9,7] etc. in spiked, synthetic liquid phases
- Knowledge gaps between the state of the art and field implementation:
  - influence of naturally occurring geochemistry and aged contamination at natural groundwater temperatures

V Method

- We have designed 1D and 2D experimental set-ups targeting electrochemical plume control in field realistic designs
  - allows for assessment of single parameters; current density, flow and electrode material, and power consumption, lateral dispersion of reactants, electrode configuration and spacing
  - replicates site conditions: Flow-through of natural groundwater with an aged contamination of PCE in a sandy aquifer material at common groundwater flow rates and temperatures

VI The field realistic design

- The field realistic parameters

<table>
<thead>
<tr>
<th>Compound</th>
<th>PCE (mg/l)</th>
<th>TCE (mg/l)</th>
<th>Cis-1,2-DCE (mg/l)</th>
<th>Trans-1,2-DCE (mg/l)</th>
<th>VC (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qp</td>
<td>25</td>
<td>11</td>
<td>12</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>k [cm²/s]</td>
<td>0.015</td>
<td>0.025</td>
<td>0.035</td>
<td>0.045</td>
<td>0.055</td>
</tr>
<tr>
<td>d (mm)</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>porosity [%]</td>
<td>31</td>
<td>32</td>
<td>33</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td>grain density [g/cm³]</td>
<td>2.67</td>
<td>2.70</td>
<td>2.72</td>
<td>2.75</td>
<td>2.77</td>
</tr>
<tr>
<td>Carbon content [%]</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Chalk content [%]</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Sampled groundwater Concentration</td>
<td>Ca²⁺ [mg/l]</td>
<td>370</td>
<td>K⁺ [mg/l]</td>
<td>4</td>
<td>Mg²⁺ [mg/l]</td>
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<tr>
<td>Sampled sand Porosity [%]</td>
<td>31</td>
<td>32</td>
<td>33</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td>Conductivity [mS/cm]</td>
<td>1.7</td>
<td>1.8</td>
<td>1.9</td>
<td>2.0</td>
<td>2.1</td>
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<tr>
<td>pH</td>
<td>6.9</td>
<td>7.0</td>
<td>7.1</td>
<td>7.2</td>
<td>7.3</td>
</tr>
</tbody>
</table>

VII Challenges and opportunities

- Contaminant fate when no current is applied is unexpected; upon test completion, dissolved and gaseous fractions are unexpected. We propose, establishment of electrochemical zones for in situ degradation of chlorinated solvents and degradation products.
- Knowledge gaps between the state of the art and field implementation:
  - influence of naturally occurring geochemistry and aged contamination at natural groundwater temperatures

IX References