Correlating Gas Phase Dispersion In Unsaturated Soils

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Outline

- Introduction
- Research Goals
- Experimental Approach
- Results
- Future Work
Introduction

- 10% of USTs in USA and Canada are currently leaking
Introduction – cont.

- Superfund Remedial Actions (EPA, 2004):
  - 35.3% SVE
  - 17.6% Bioremediation/Bioventing
Bioventing and SVE Modeling

- Advection-dispersion equation

$$\frac{\partial c}{\partial t} = D_L \frac{\partial^2 c}{\partial x^2} - v \frac{\partial c}{\partial x} \pm \sum r_i$$

- Longitudinal Dispersion Coefficient

$$D_L = \alpha v + D_{Diff}$$
SVE and Bioventing

- Rule of Thumb Design

- Models
  - Performance estimates
  - Lack of reliable coefficients
Dispersion

- Gradual spreading and mixing of solute with advective flow
  - Velocity Gradients
  - Concentration Gradients
Dispersion Mechanisms

- Path Tortuosity
- Friction in Pore
- Pore Size
Dispersion Mechanisms

- Path Tortuosity
- Friction in Pore
- Pore Size
Research Goals - Overall

Soils Research Group

- MTC
- Dispersion
- Biological Degradation

SVE and BV Models
Research Goals - Dispersion

- **Phase I**
  - Develop experimental apparatus
  - Develop correlations
  - Disturbed soils

- **Phase II**
  - Test correlations on field core samples
  - Modify correlations for field predictions
Methodology

- 1-D Non-Reactive Tracer experiments
- Open Vessel Boundary Conditions
### Methodology – cont.

#### Soil and Columns

<table>
<thead>
<tr>
<th>Soil Properties</th>
<th>OS</th>
<th>SLS</th>
<th>ESL</th>
<th>BC</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Sand (by weight)</td>
<td>98.8</td>
<td>69.4</td>
<td>34.0</td>
<td>21.0</td>
</tr>
<tr>
<td>% Silt (by weight)</td>
<td>1.2</td>
<td>24.4</td>
<td>50.1</td>
<td>35.1</td>
</tr>
<tr>
<td>% Clay (by weight)</td>
<td>0</td>
<td>6.2</td>
<td>15.9</td>
<td>43.9</td>
</tr>
</tbody>
</table>

- OS – Ottawa Sand
- SLS – Simcoe Loamy Sand
- ESL – Elora Silt Loam
- BC – Brookston Clay

#### Water Content

- Air Dry (~5%) to Field Capacity
Methodology - cont.

- **Tracer Injection**
  - Solenoid Valve
  - Tracer - Helium
  - Carrier - Nitrogen

- Two sampling locations
Methodology – cont.

- Thermal Conductivity Detector (TCD)
- Real-Time Data Collection
  - NI DAC
  - LabVIEW
Experiment Schematic
Data Analysis

- Residence Time Distribution
  - Variance, Mean residence time, Dispersion

![Graph showing TCD response over time for Channel 1 and Channel 2 with labels for \( s^2_1 \) and \( s^2_2 \).]
Results

- New, working apparatus
  - Disturbed
  - Undisturbed
Results - cont’d

- Preliminary Air Dry Ottawa Sand
  - Dispersivity ($a$) = 0.042 cm

- Gidda et al. (2004)

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Moisture Content</th>
<th>Observed Dispersivity (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ottawa Sand</td>
<td>Air Dry</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>3%</td>
<td>1.2</td>
</tr>
<tr>
<td>Delhi Loamy Sand</td>
<td>Air Dry</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>2.6</td>
</tr>
<tr>
<td>Elora Silt Loam</td>
<td>Air Dry</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>1.9</td>
</tr>
<tr>
<td>Brooksten Clay</td>
<td>Air Dry</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>2.4</td>
</tr>
</tbody>
</table>
Discussion

- Reliable dispersivity values
- SVE and BV

  - Improved closure predictions
  - Improved system designs
Future Work

- Disturbed soil are ongoing
- Collect field core samples
- Compare results with correlations
Acknowledgements

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- Eyad Barakat
Thank You

Questions / Comments ?