Cryptosporidium Transport in Unsaturated Flow

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USEPA/USGS Meeting – Cryptosporidium Removal by Bank Filtration
September 10, 2003 – Reston, Virginia
Structure of Seminar

- Preferential Flow and Vadose Zone
- Preferential transport of solute/biocolloid Cryptosporidium parvum oocysts through vadose zone
- Take-home Messages
Vadose Zone

Stream

Well

Ground surface

Soil Water Zone

Intermediate Zone

Capillary Zone

Groundwater Zone

Groundwater

Pellicular & gravitational water

Subsurface Water

Ground surface

Vadose Zone (Unsaturated Zone)

Water Table

Saturated Zone
Preferential Flow

- Process
  - By-pass transport phenomena
  - Concentration of flow into channels at soil surface or subsurface

- Types
  - Macropore flow
  - Fingered flow
  - Funneled flow

- Impacts on water resources
  - Non-point sources pollution
  - Water quality
Preferential Transport of Cryptosporidium

- Characterize the fate and transport of Cryptosporidium in the subsurface environment
- Modeling of solute and biocolloid transport

**Issues**

- *Cryptosporidium parvum*
  - 4-6 µm diameter
  - Found in feces of infected animals
  - Protozoan pathogen that causes Cryptosporidiosis

- Source of *Cryptosporidium parvum*
  - Application of manure to farm fields
  - Wild animals

- *Cryptosporidium* in drinking water
  - Resistant to chlorination
Laboratory Experiments

- Laboratory column experiments
  - Cryptosporidium parvum from calves feces
  - Rainfall simulation event
  - Different porous media: silica sand, water repellent sand, sand with water repellent layers
  - Undisturbed soil columns
  - Mixture of Cryptosporidium parvum and a tracer (chloride)
Dye-uptake types

(Anguish L.J. and W.C. Ghiorse. 1997)

- Nonviable oocysts: permeable to DAPI and PI
- Viable oocysts: impermeable to DAPI and PI, or permeable to DAPI only

**Microbiology Analysis**

- Oocysts Visualization & Viability
  - Immunofluorescence Staining
  - Dye Permeability Assay
- Soil extraction protocol
  - Tween & gradient concentration by centrifugation
- Fluorescence Microscopy
Results

- Visualization of preferential flow path
- Visualization, quantification of oocysts
- Breakthrough curves (BTC)
- *Cryptosporidium* distribution and water saturation in soil profile
- Modeling of solute and colloid transport
Visualization of Fingered Flow

Water Fingered Flow in Sand

3D - 2D Visualization & Fluid Content Profile
BTC of Cl and Oocysts & Soil Profile Distribution of Water and Oocysts

1 cm/hr rainfall, 12/20 sand
BTC of Cl and Oocysts & Soil Profile Distribution of Water and Oocysts

2 cm/hr rainfall, 12/20 sand
BTC of Cl and Oocysts & Soil Profile Distribution of Water and Oocysts

1 cm/hr rainfall, 12/20 sand
with two water repellent interfaces layers
Undisturbed Soil Column

Cl (C/Co)

Rain (cm)

- Chloride
- Oocysts

Oocysts (C/Co)
BTC of Cl and Oocysts
Schematic and Model for Preferential Flow

Distribution Layer (DL)
Exponential loss of solutes/colloids

\[ C = C_0 \exp(-\lambda t) \]

Conveyance Zone (CZ)
Convective-dispersive equation

\[ \frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2} - v \frac{\partial C}{\partial t} \]
**Observed & Predicted BTC**

**Solutes concentration**

\[
C = \frac{1}{2} C_0 \exp(-\lambda t) \left[ \exp \left( \frac{vx}{2D}(1-\alpha) \right) \text{erfc} \left( \frac{x-vt\alpha}{2\sqrt{Dt}} \right) + \exp \left( \frac{vx}{2D}(1+\alpha) \right) \text{erfc} \left( \frac{x+vt\alpha}{2\sqrt{Dt}} \right) \right]
\]

**Colloids concentration**

\[
C = \frac{1}{2} C_0 \exp \left( -\left( \frac{q}{W+\beta} \right) t \right) \left[ \exp \left( \frac{vx}{2D}(1-\alpha') \right) \text{erfc} \left( \frac{x-vt\alpha'}{\sqrt{4Dt}} \right) \right]
\]
Unsaturated Zone and Bank Filtration

• Unsaturated zone and its occurrence in bank filtration
  – well production over-pumping
  – during high river stage
  – flooding of dry river bench

• Unsaturated zone and its role in fate and transport of contaminants
  – preferential transport phenomena
  – gas-water interfaces
  – physical, chemical and biological processes
  – contaminants attenuation and entrapment
Demonstrated fast transport of *Cryptosporidium parvum* oocysts by fingered and macropores flow through vadose zone

Experiments results suggest that human pathogens, like *Cryptosporidium parvum* oocysts, can be rapidly transported to significant depths in situations where preferential flow occurs

Gas-water interfaces limit the movement of oocysts

Modeled preferential transport of solutes and colloids

Unsaturated zone and its importance in bank filtration
Acknowledgements

Cornell University, USA
U. S. Department of Agriculture