Role of Directly Connected Macropores in the Transport of *E. coli* to Subsurface Drainage

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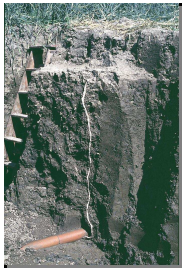
Introduction

The primary transport of pathogenic microorganisms in soils occurs through macropores that bypass the filtering and adsorptive effects of the soil matrix. Recent research indicates immediate breakthrough of solutes and contaminants in subsurface drainage by extraordinarily efficient transport through directly connected macropores. Other researchers have reported field experiments with no significant pathogen concentrations from subsurface drain flow, suggesting that pathogen transport to subsurface drainage systems is field specific. It is hypothesized that one of the primary reasons for field specific pathogen transport to subsurface drainage systems is related to the presence or absence of directly connected macropores that are "hydrologically" connected to subsurface drainage systems.

Background

- Primary transport of pathogenic microorganisms in soils occurs through macropores that bypass the soil's filtering and adsorptive effects
- Without macropores, downward percolation of pathogens through the soil matrix is generally insignificant
- Recent research indicates immediate breakthrough of solutes and contaminants, including *E. coli*, in subsurface drainage by directly connected macropores



Macropore Connected to Drain
(Picture courtesy of V. Nuutinen and K. Butt

Macropore Connected to Drain
(Picture courtesy of Martin Shipitalo)

- Shipitalo and Gibbs (2000) observe macropores created by deep burrowing species of earthworms (*Anecic*) in a silt loam soil that allow water to transfer directly to subsurface drains
- Injected smoke into drain lines to observe transmission to the soil surface
- Smoke emitting macropores were located within 50 cm of the drain line and the distance from the subsurface drains correlated to infiltration rate.

- The objective of this research is to investigate the significance of directly connected macropores on *E. coli* transport to subsurface drainage.
- Initial field experiments performed at the Iowa State University Northeast Research Station near Nashua, IA
- Laboratory soil column experiments using the innovative macropore design to investigate *E. coli* transport under controlled conditions.

Earthworm holes (macropores) in soil blocks
from Nashua, IA

Field Experiments

Smoke Injection to Document Directly-Connected Macropores

- Experiments conducted in continuous soybean, no-till drainage plot
- Smoke injected at the outlet of the subsurface drain and pushed backed into the tile line

- Smoke emitting macropores flagged
- Most smoke plumes were within a 25-cm wide band over the drain
- Observed both concentrated (i.e., smoke originating from open, visible macropore, surface connected) and diffuse (i.e., not originating from one macropore, potentially from non-surface connected) smoke plumes
- Smoke tests resulted in approximately 3.1 macropores per meter with 0.6 "concentrated smoke" macropores per meter

Macropore Infiltration Tests

- Infiltration rate measured for flagged macropores located directly above or adjacent to the subsurface drain and also identifiable macropores located approximately 2 to 3 m from the subsurface drain
- Infiltration rate measured using a fall-head infiltrometer
- Initial results: infiltration rate of macropores located within 50 cm of the tile drain (0.4 L/min for 3 macropores) were not higher than the infiltration rate of macropores located 2 to 3 m from the drain (0.5 L/min for 2 macropores)

Liquid Swine Manure Application and Irrigation

- Liquid swine manure applied at rate of 50 lb N/acre
- *E. coli* concentrations in swine manure of 43,000 to 85,000 MPN/100 mL

- Irrigation applied 24 hours after liquid swine manure application
- Irrigation applied using a linear move irrigation system
- Total rainfall input was approximately 2.54 cm
- Irrigation did produce isolated shallow ponding for approximately 15 minutes after irrigation.

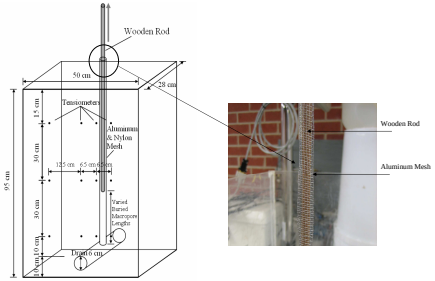
Monitoring Drain Flow for *E. coli*

- Water samples obtained from the drain line for 24 hours
- Even with this relatively small rainfall input, positive detections of *E. coli* were detected in two of the drain flow samples at small concentrations (i.e., <5 MPN/100 mL) approximately one hour after rainfall initiation
- Samples after one hour contained no detectable *E. coli*

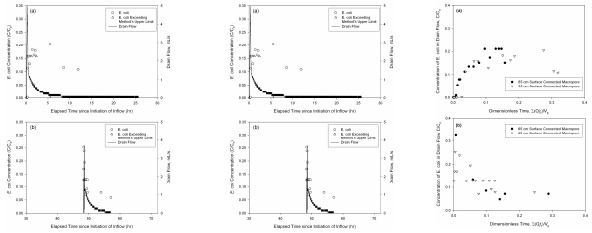
Laboratory Experiments

- Soil column packed with a loamy sand soil (84.5% sand, 13.4% silt, and 2.1% clay) to a bulk density of 1.6 g/cm^3
- Two laboratory column studies using soil column of Akay and Fox (2007) with macropores located above the subsurface drain:
  - Surface-connected macropores of 55 cm (i.e., 20 cm of soil between the macropore and drain) and 65 cm in length (i.e., 10 cm between the macropore end and the drain)
- Distilled water containing 11,500 MPN/100 mL of *E. coli* applied to the top of the soil column to maintain a constant 1-cm ponded boundary condition for 90 minutes
- *E. coli* monitored in drain flow during a drainage period of approximately 48 hr
- Column flushed with distilled water to determine the concentration of *E. coli* remaining in the soil column

Laboratory soil column developed by Akay and Fox (2007) to simulate both surface-connected and buried macropores directly connected to a subsurface drain



E. coli in drain flow following (a) manure application and (b) distilled water flush (48 hr after manure)



55-cm Surface Connected Macropore *65-cm Surface Connected Macropore* *Comparison of Experiments*

Future Work

- Two future field experiments planned each year for the next two years with paired subsurface drained plots: one with directly connected macropores and one with a reduced number of active macropores
- Additional laboratory experiments encompassing a wider range of conditions with both surface connected and buried macropores:
  - Soil types: loamy sand and Floyd loam
  - Macropores shifted at various distances from drain

References

- Akay, O. and Fox, G.A. (2007). "Experimental investigation of direct interconnectivity between macropores and subsurface drains during infiltration." Soil Science Society of America Journal, 71(5), 1600-1606.
- Shipitalo, M.J., and Gibbs, F. (2000). "Potential of earthworm burrows to transmit injected animal wastes to tile drains." Soil Science Society of America Journal, 64, 2103-2109.