

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

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## Introduction

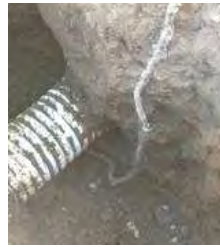
The primary transport of pathogenic microorganisms in soils occurs through macropores that bypass the filtering and adsorptive effects of the soil matrix. Recent research indicates immediate breakthrough of solutes and contaminants in subsurface drainage by extraordinarily efficient transport through directly connected macropores. 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 (i.e., biopores) that are "hydrologically" connected to subsurface drainage systems.



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



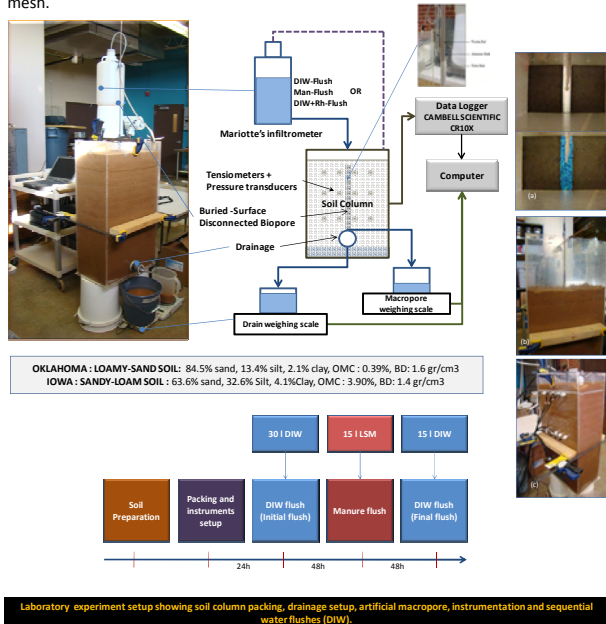
Earthworm holes (macropores) in soil blocks from Nashua, IA



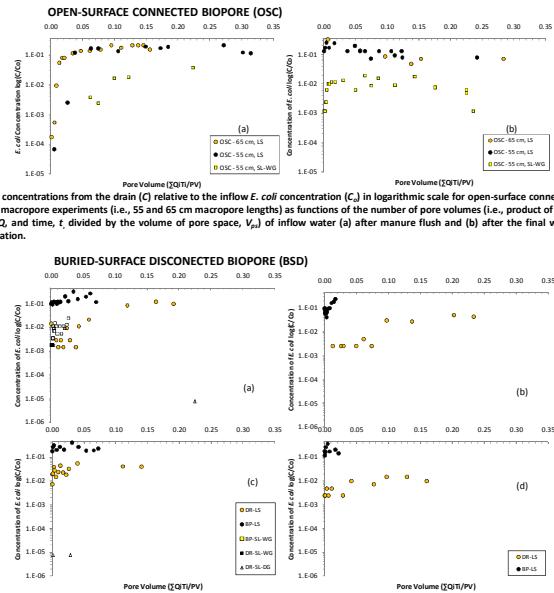
Macropore Connected to Drain (Picture courtesy of Martin Shpitalno)

## Laboratory *E. coli* Transport Experiments

An innovative soil column (28x50x85 cm) was packed with two types of soils to investigate the transport of *E. coli* under the presence of artificial open-surface connected and buried-disconnected biopores. The macropore was built by rolling a metallic mesh around a 6-mm diameter wooden stick and covering with a plastic mesh.



## *E. coli* Breakthrough Curves



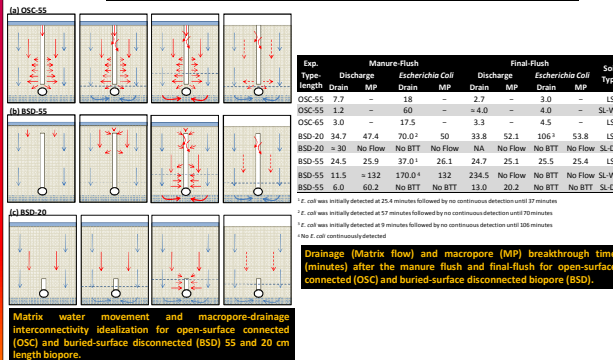
*E. coli* concentrations from the drain (C) relative to the inflow *E. coli* concentration (C<sub>i</sub>) in logarithmic scale for open-surface connected (OSC) macropore experiments (i.e., 55 and 65 cm macropore lengths) as functions of the number of pore volumes (i.e., product of flow rate, Q, and time, t, divided by the volume of pore space, V<sub>p</sub>) of inflow water (a) after manure flush and (b) after the final water application.

*E. coli* concentrations from the drain (C) relative to the inflow *E. coli* concentration (C<sub>i</sub>) in logarithmic scale for buried-surface disconnected (BSD) biopore experiments (i.e., 55 and 20 cm macropore lengths) as functions of the number of pore volumes (i.e., product of flow rate, Q, and time, t, divided by the volume of pore space, V<sub>p</sub>) of inflow water. Figures (a) and (b) are after manure flush for the 55-cm and 20-cm BSD, respectively. Figures (c) and (d) are after the final water application for 55-cm and 20-cm BSD, respectively.

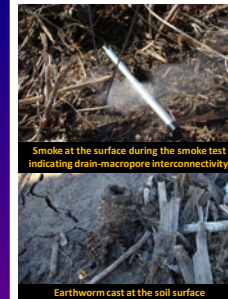
## Soil Column and Subsurface *E. coli* Transport

*Escherichia coli* normalized concentration recovery in the drain (Matrix flow) and macropore (MP) after the manure flush and final-flush for open-surface connected (OSC) and buried-surface disconnected (BSD) biopore.

Type	Macropore Length (cm)	<i>E. coli</i> C <sub>i</sub> (MPN/100mL)	Matrix Flow		Macropore Flow		Soil Type
			Man-Flush	Final-Flush	Man-Flush	Final-Flush	
OSC	55	15,400	0.20Co	0.25Co	-	-	LS
OSC	55	8,355	0.04Co	0.02Co	-	-	SL-WG
OSC	65	11,500	0.21Co <sup>a</sup>	0.32Co	-	-	LS
BSD	20	4,130	0.05Co	0.01Co	0.24Co	0.37Co	LS
BSD	20	15,000	0	0	No Flow	No Flow	SL-DG
BSD	55	7,140	0.12Co	0.05Co	0.32Co	0.41Co	LS
BSD	55	5,771	0.002Co	0	0.023Co	No Flow	SL-WG
BSD	55	133,078	7.51E-6Co	7.51E-6Co	0	0	SL-DG



## Field Experiments at Nashua, IA

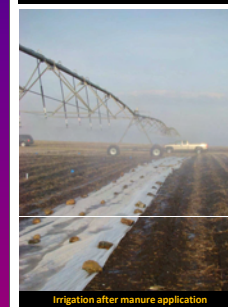


Smoke at the surface during the smoke test indicating drain-macropore interconnectivity.

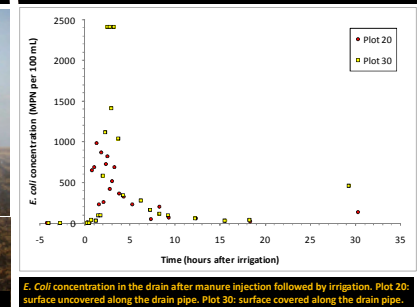
Earthworm cast at the soil surface



Field manure injection at the Northeast ISU research farm, Nashua, IA



Irrigation after manure application



*E. coli* concentration in the drain after manure injection followed by irrigation. Plot 20: surface uncovered along the drain pipe. Plot 30: surface covered along the drain pipe.

Field experiments conducted at the Northeast Iowa State University research farm.

## Conclusions

- Results from this study indicated the efficiency of *E. coli* transport to drainage systems under the presence of interconnected open-surface connected or buried-surface disconnected biopores.
- Soil macropores and large mesopores play an important role in allowing the movement of pathogens to deeper soils after irrigation or rainfall events.
- Soils with small soil pore spaces (e.g., micropore and small mesopores) and sorptive properties can filter *E. coli* in most of the cases due to the development of physical and biological straining as well as adsorption. Additionally, low velocities in the soil pore spaces may allow *E. coli* to resist being transported by its auto-propulsion and adhesion capabilities.

### LABORATORY EXPERIMENTS

- The occurrence of large soil pore spaces in contact with the biopore increased the water flux into the biopore from the matrix.
- Soil sorptive properties play an important role in defining the available *E. coli* concentration for transport through the matrix and biopores.
- In OSC biopores, *E. coli* transport to the drain was primarily a function of the soil type and the soil layer thickness between the end of the biopore and the drain.
- The BSD biopores contributed flow and *E. coli* to the drain only in less sorptive soils (i.e., LS) and in sorptive soils (i.e., SL) containing a wide (i.e., with mesopores) as opposed to a uniform pore space distribution.

### FIELD EXPERIMENTS

- Maximum *E. coli* concentration recovery in the drainage system after manure injection followed by irrigation was 0.03% of the initial concentration.