

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

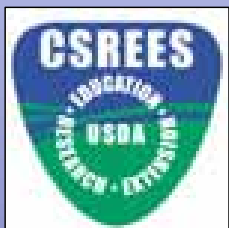
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Garey A. Fox

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OKLAHOMA STATE UNIVERSITY



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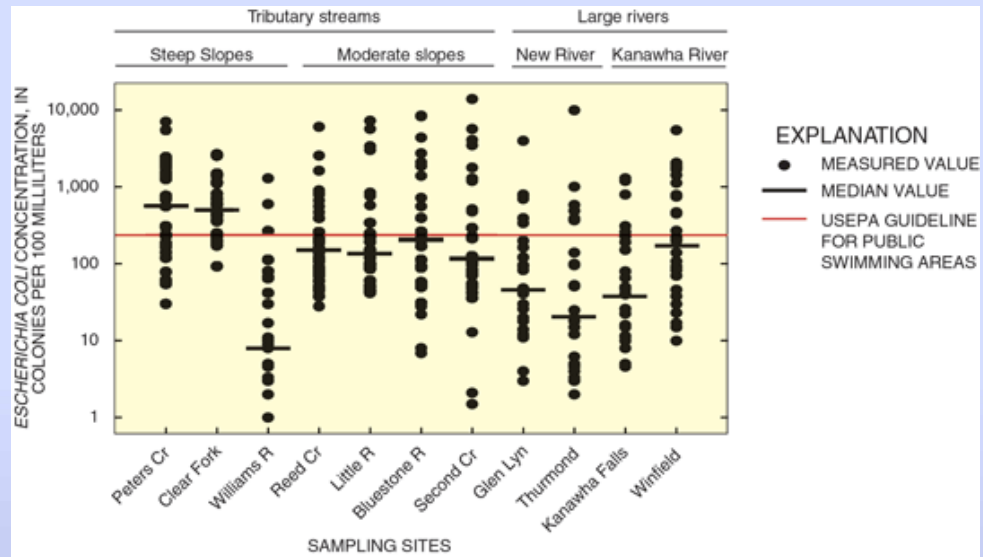
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## Biological Contaminants

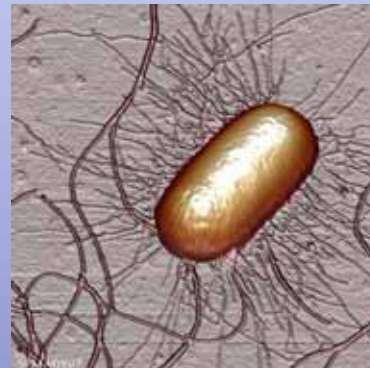
- Significant cause of water quality degradation
- Measured by indicator organisms

## Transport and Fate

- Planctonic form
- Attached to
  - Colloids
  - Organic matter
  - Mineral particles
- Re-growth
- Die-off



[pubs.usgs.gov/circ/circ1204/major\\_findings2.htm](https://pubs.usgs.gov/circ/circ1204/major_findings2.htm)





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Drainage-Biopores  
Interconnectivity

↓

Rapid breakthrough of  
solute and  
contaminants

**Smoke Test at the  
Northeast ISU  
Research farm**





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## MACROPORES

Large and continuous pore space openings

### Natural Fractures

### Cylindrical Biopores



**Superficial Cracks**



**Deep Fractures**

**Roots**  
*Anecic* earthworms  
 $\varnothing \approx 2.5$  to 13 mm

**Ants**  
**Armadillos**  
 $\varnothing \approx 30.5$  to 91.5 cm  
**Groundhog**  
 $\varnothing \approx 15$  to 25.4 cm  
**Mole**  
 $\varnothing \approx 2$  cm



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

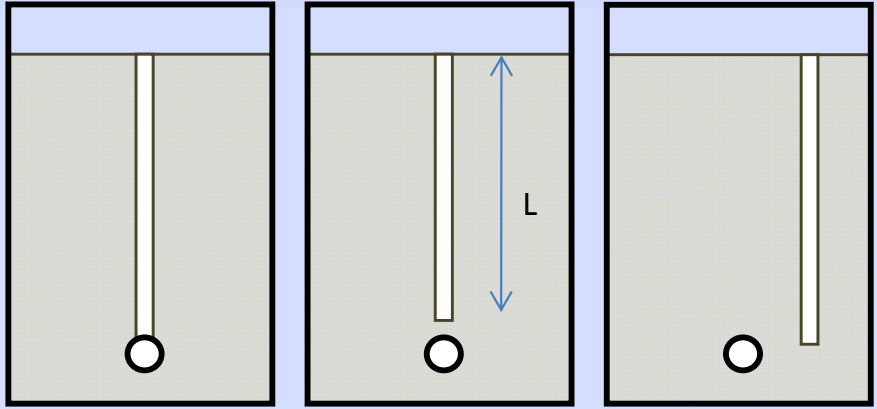


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Type I

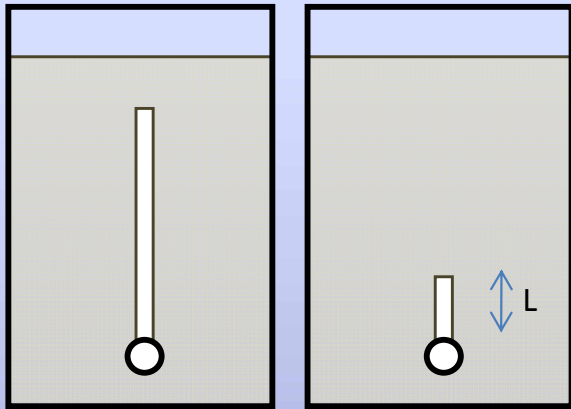
Open Surface Connected



OSC

Type II

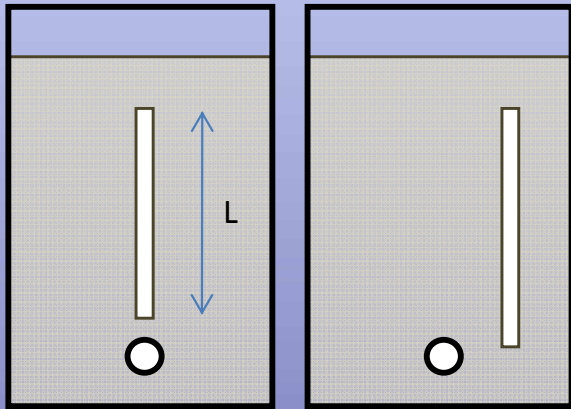
Buried Surface Disconnected



BSD

Type III

Buried Disconnected



BD



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



Macropore Connected to Drain  
(Picture courtesy of Martin Shipitalo)



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## OBJECTIVES

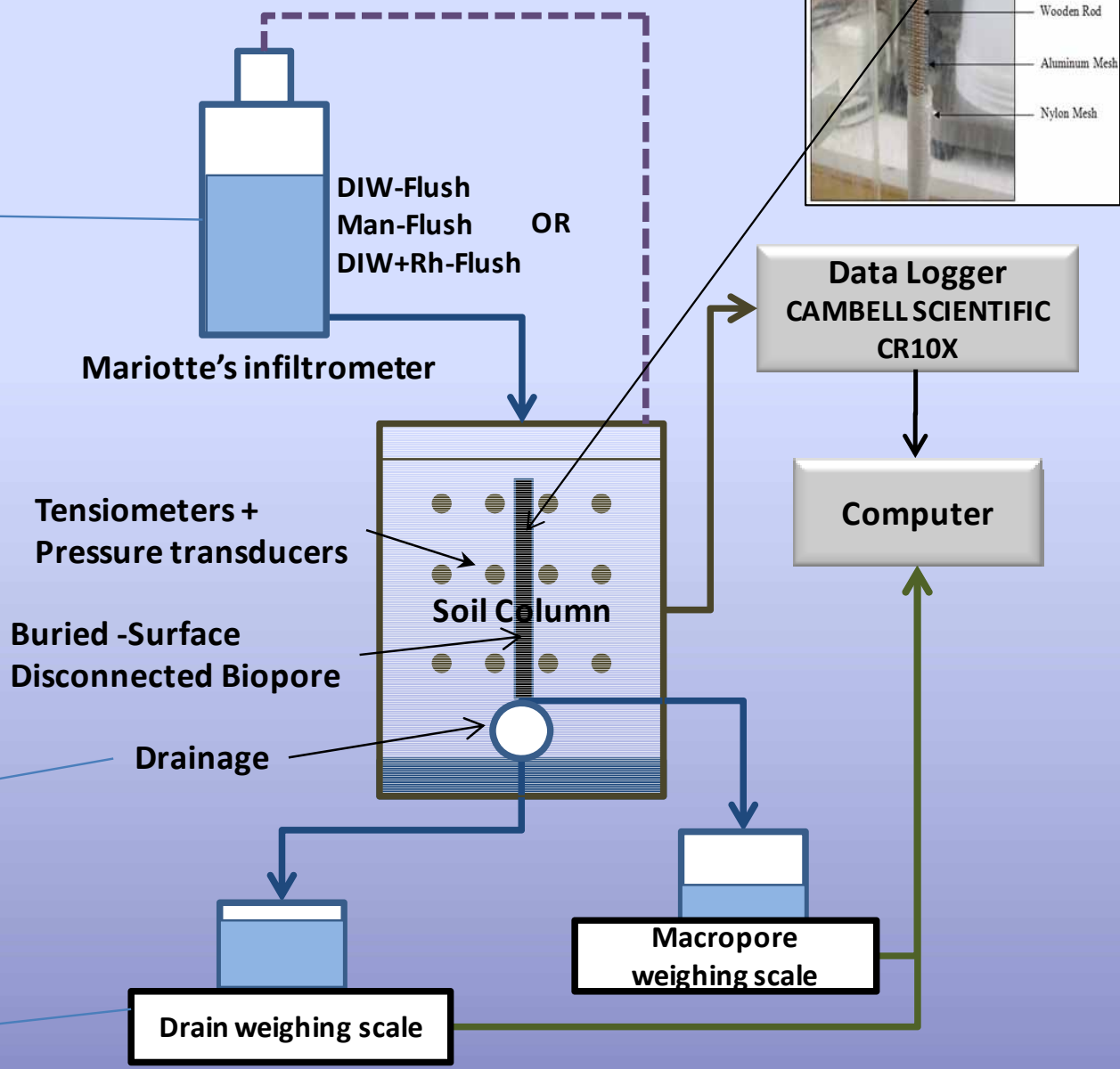
The objective of this research was to investigate the significance of directly connected macropores on *E. coli* transport to subsurface drainage.

Laboratory experiments of *E. coli* transport through OSC and BSD biopores were performed using the soil column developed by Akay and Fox (2007).



# THE ROLE OF DRAINAGE SYSTEM AND MACROPORE INTERCONNECTIVITY IN SOIL PATHOGEN TRANSPORT

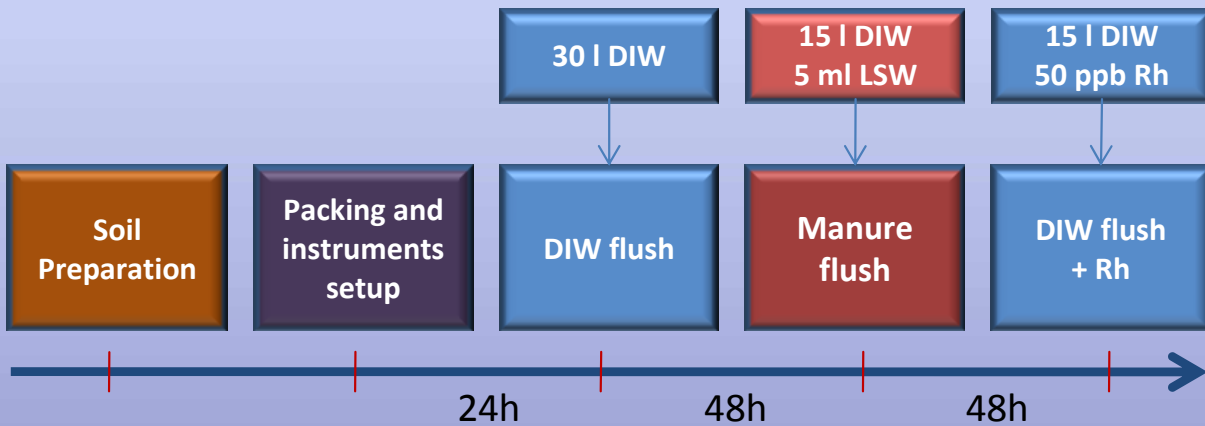
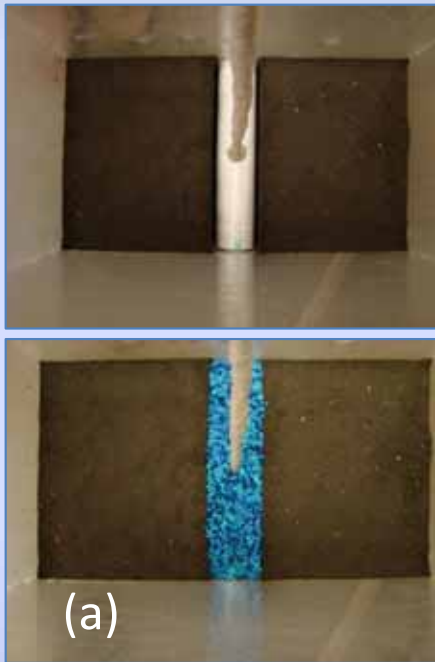
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# THE ROLE OF DRAINAGE SYSTEM AND MACROPORE INTERCONNECTIVITY IN SOIL PATHOGEN TRANSPORT

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**OKLAHOMA : LOAMY-SAND SOIL:**  
 84.5% sand, 13.4% silt, 2.1% clay, OMC : 0.39%, BD: 1.6 gr/cm<sup>3</sup>

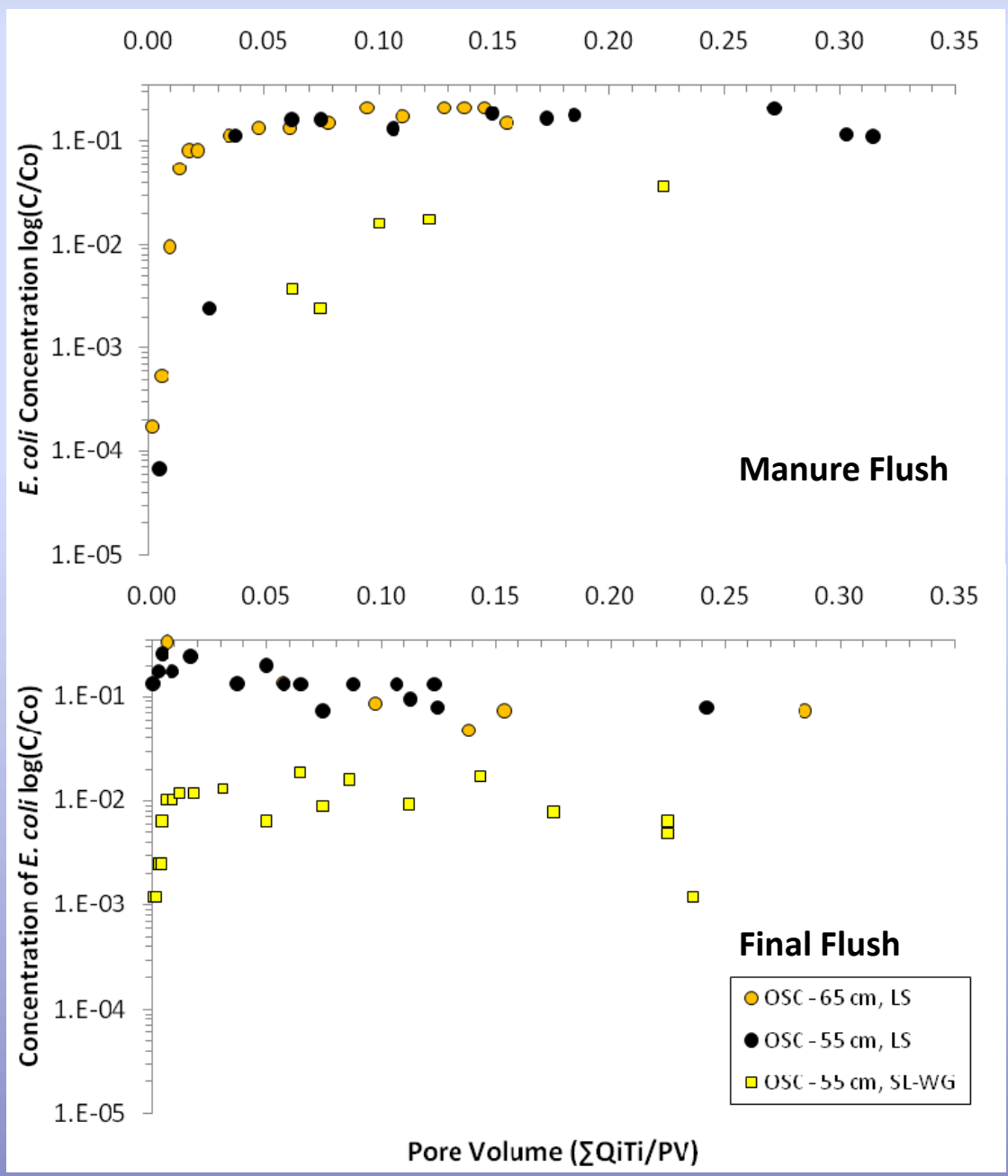
**IOWA : SANDY-LOAM SOIL :**  
 63.6% sand, 32.6% Silt, 4.1%Clay, OMC : 3.90%, BD: 1.4 gr/cm<sup>3</sup>



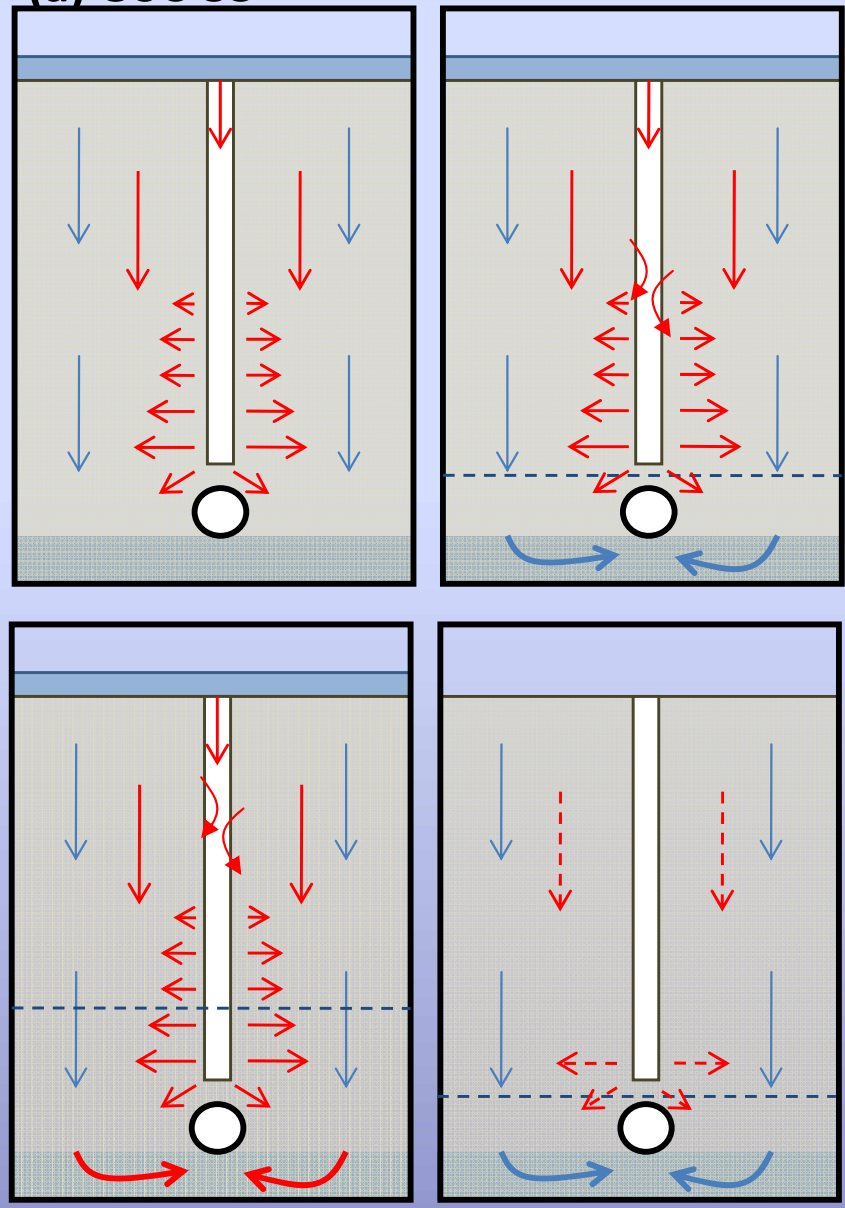


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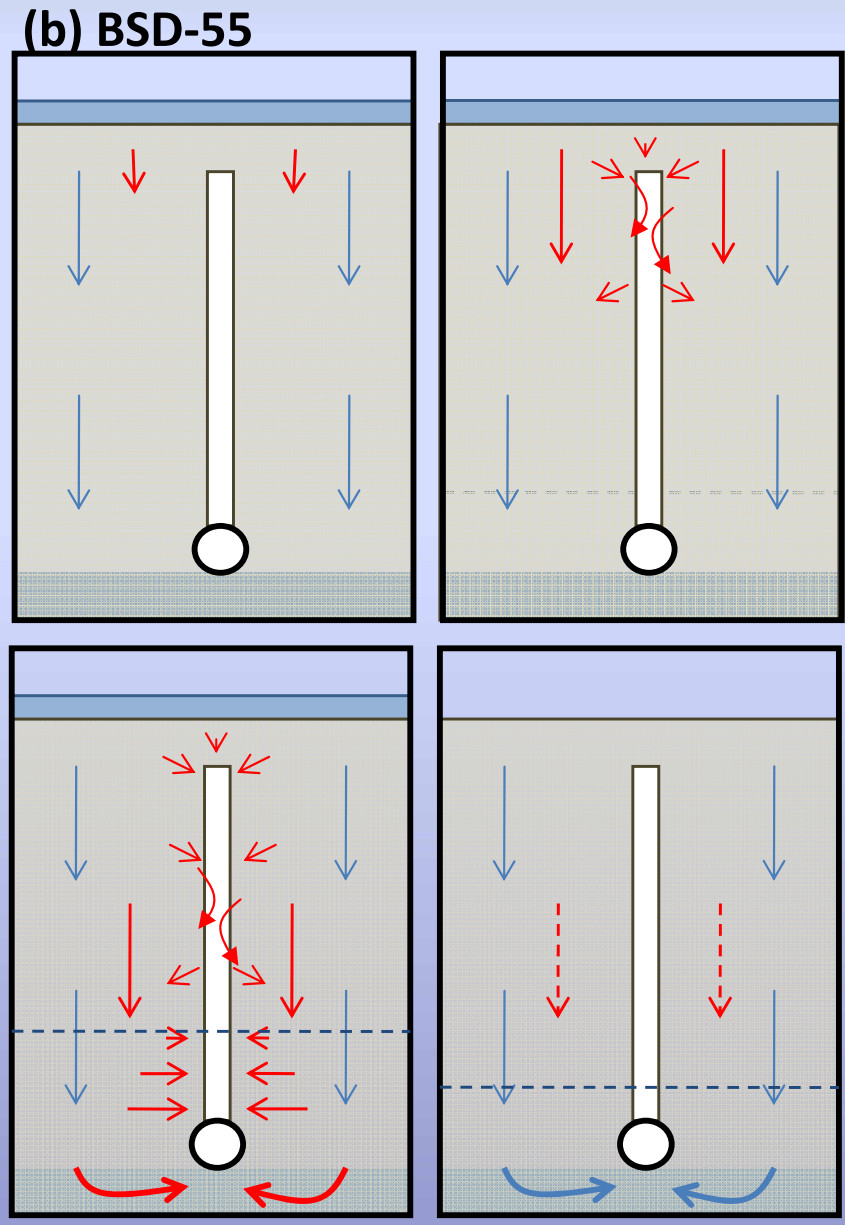
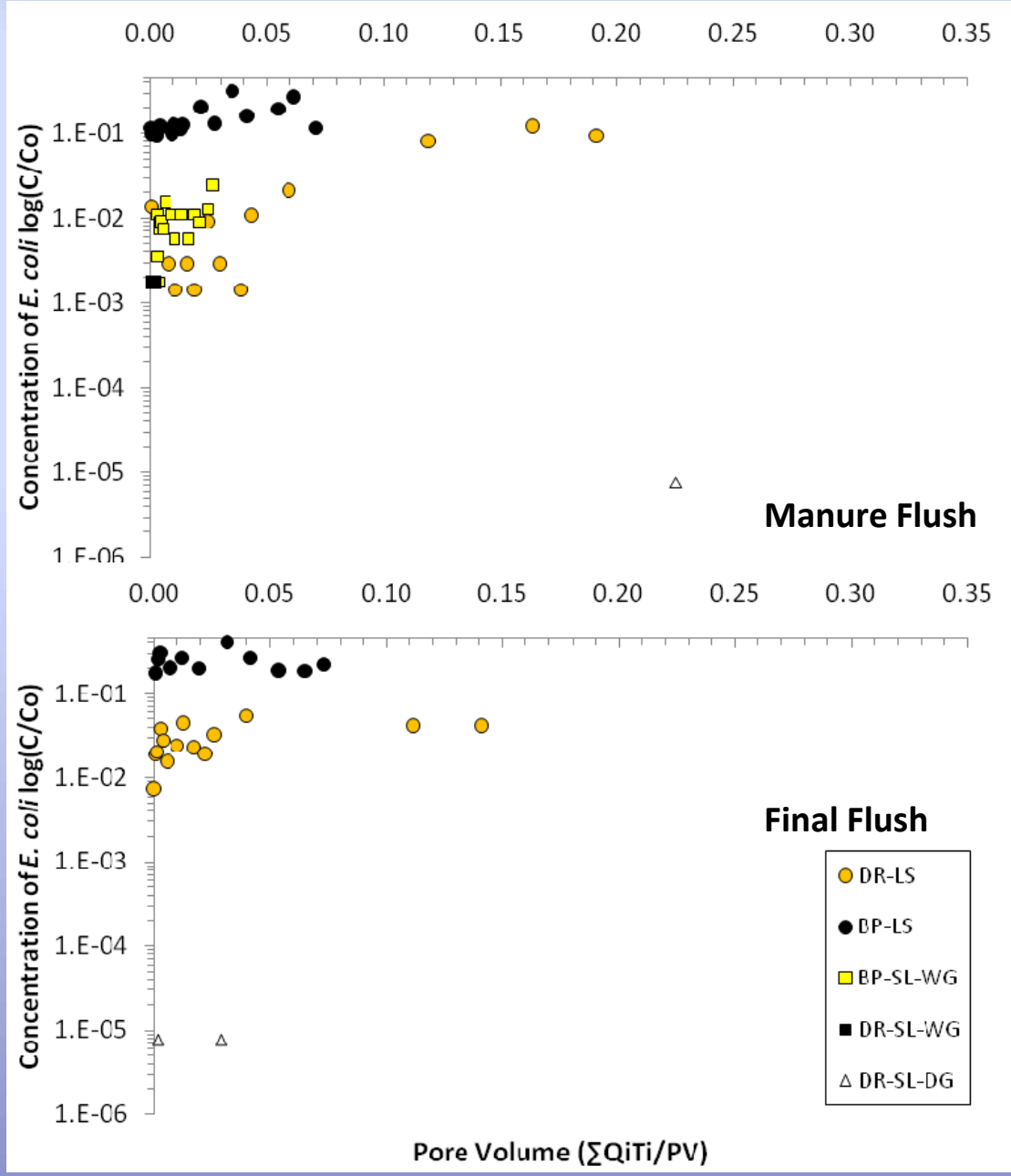
(a) OSC-55





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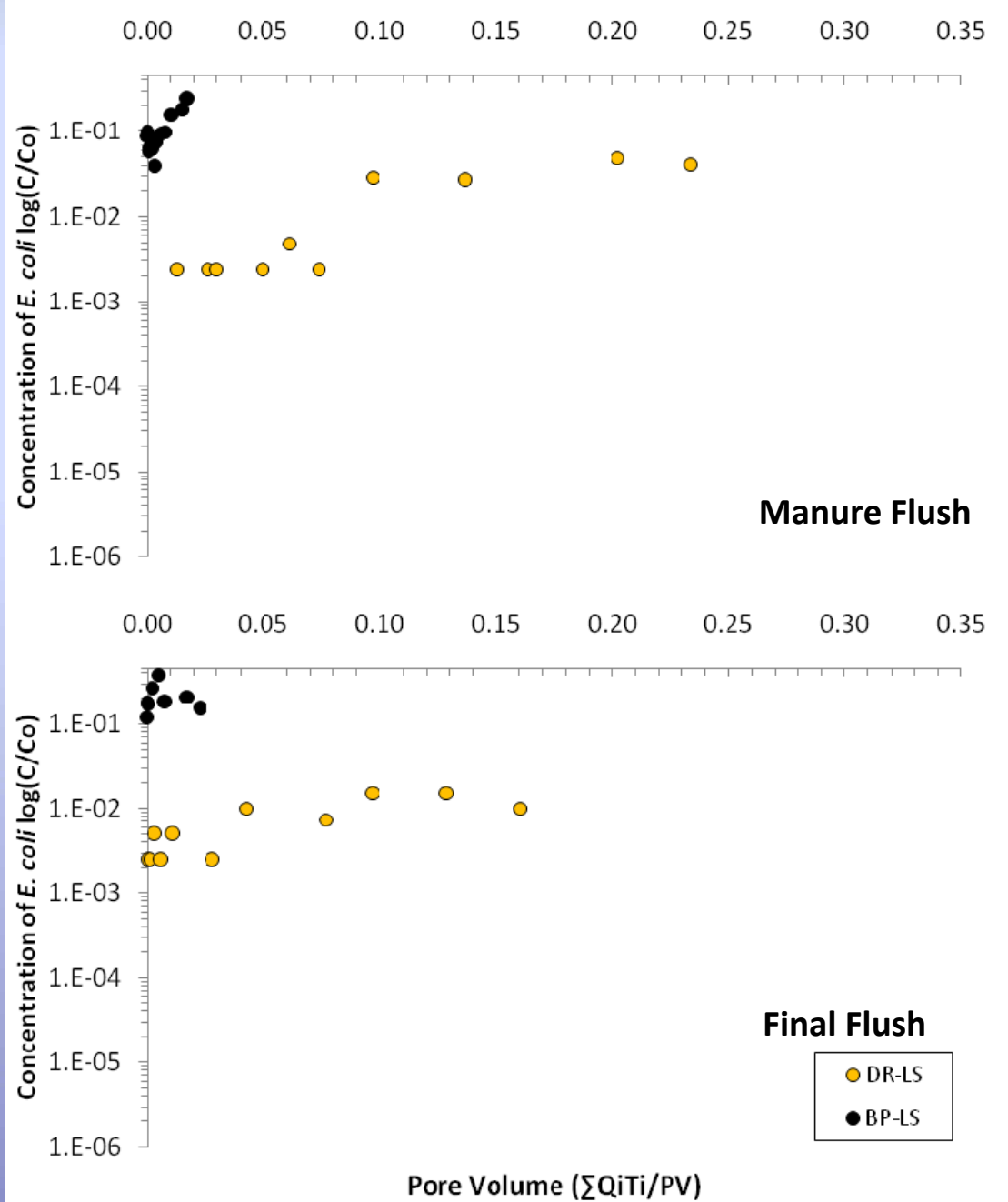
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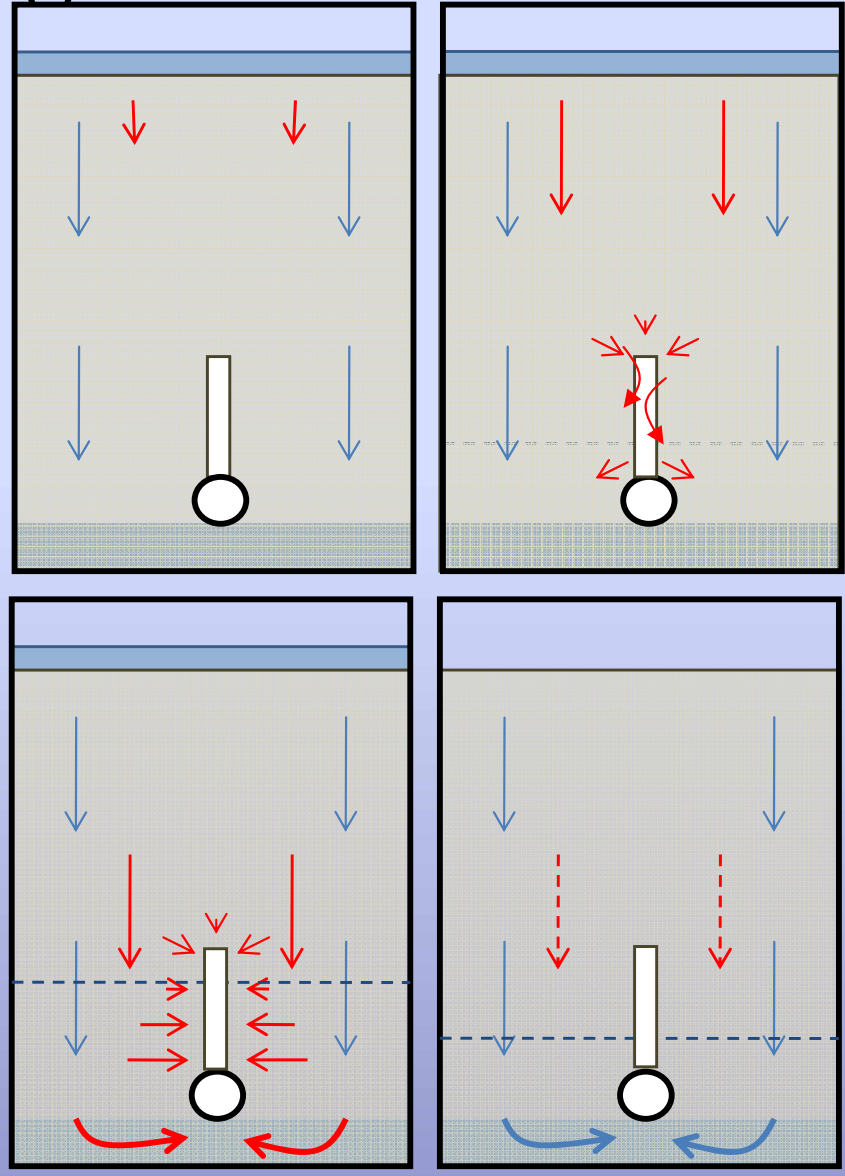


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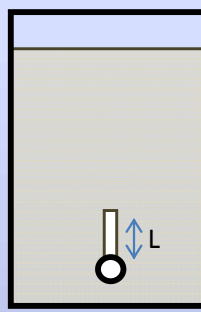
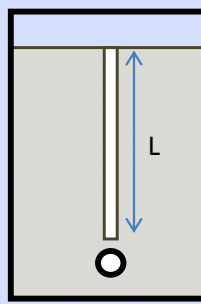
(c) BSD-20





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Type	Macropore Length (cm)	<i>E. coli</i> C <sub>0</sub> (MPN/100mL)	Matrix flow		Macropore flow		Soil Type
			Man-Flush	Final-Flush	Man-Flush	Final-Flush	
OSC	55	15,400	0.20C <sub>0</sub>	0.25C <sub>0</sub>	–	–	LS
OSC	55	8,355	0.04C <sub>0</sub>	0.02C <sub>0</sub>	–	–	SL-WG
OSC	65	11,500	0.21C <sub>0</sub> <sup>1</sup>	0.32C <sub>0</sub>	–	–	LS
BSD	20	4,130	0.05C <sub>0</sub>	0.01C <sub>0</sub>	0.24C <sub>0</sub>	0.37C <sub>0</sub>	LS
BSD	20	15,000	0	0	No Flow	No Flow	SL-DG
BSD	55	7,140	0.12C <sub>0</sub>	0.05C <sub>0</sub>	0.32C <sub>0</sub>	0.41C <sub>0</sub>	LS
BSD	55	5,771	0.002C <sub>0</sub>	0	0.023C <sub>0</sub>	No Flow	SL-WG
BSD	55	133,078	7.51E-6C <sub>0</sub>	7.51E-6C <sub>0</sub>	0	0	SL-DG





## CONCLUSIONS

- Results indicated the efficiency of *E. coli* transport to drainage systems under the presence of interconnected open-surface connected or open-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 and sorptive properties can filter *E. coli* in most of the cases. Additionally, low velocities in the soil pore spaces may allow *E. coli* to resist being transported by its auto-propulsion and adhesion capabilities.

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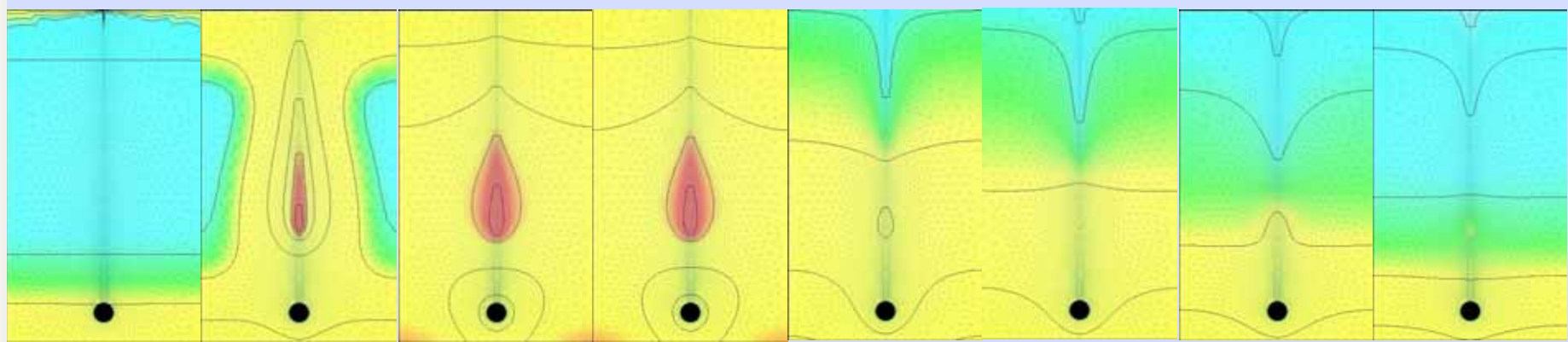
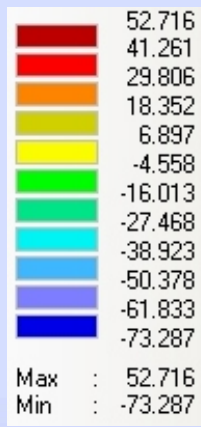
**Research Website:** <http://biosystems.okstate.edu/Home/gareyf>



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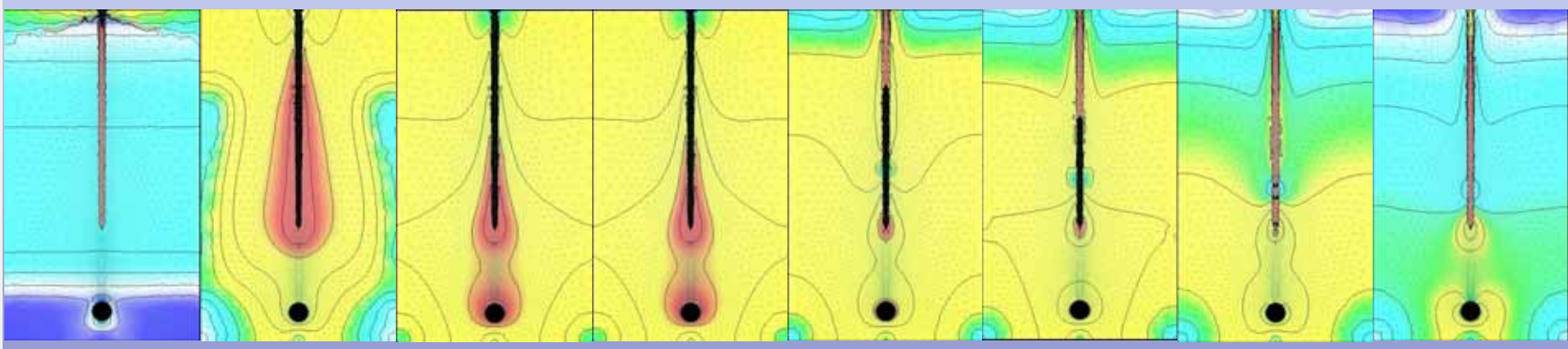
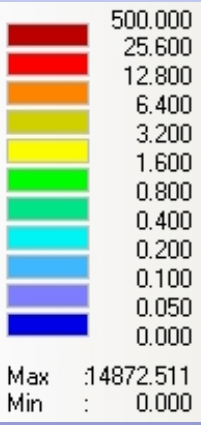
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## Pressure Head (cm)



Time (min)    0                    10                    20                    40                    50                    60                    90                    180

## Velocity (cm/h)



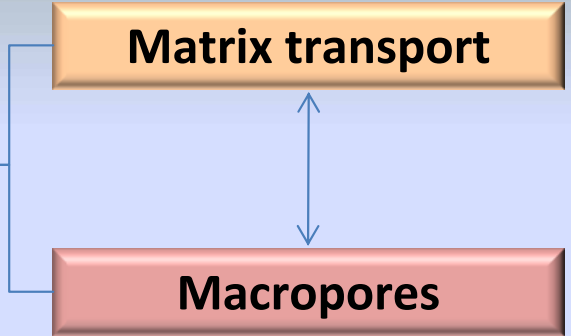


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## SOIL BACTERIA TRANSPORT

- Dispersion
- Advection
- Physical straining
- Biological straining
- Attachment
- Detachment
- Adhesion
- Motility
- Chemotaxis
- Growth
- Inactivation
- Physiological death
- VBNC
- Predation
- Competition
- Amensalism



## Physical and Biological Straining

