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Role of Directly Connected Macropores on Pathogen Transport to Subsurface Drainage Water

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Abstract
Pathogen contamination of water supplies is now considered one of the top water quality issues in the United States and worldwide. Continual application of livestock manure may contribute to nonpoint source pollution by releasing microbial pathogens including bacteria, virus, and protozoa, through runoff and subsurface drainage water to surface and ground water. Many studies have been conducted in the laboratories and fields to understand the preferential flow through macropores. But no experiments in the field have been conducted to examine the breakthrough curve of pathogen and/or Escherichia coliform (E.coli) with directly connected macropores. The objective of this research is to address the transport of pathogens (specifically the indicator organism E. coli) through soils, and more specifically the role of macropores in the transport of E. coli to subsurface drains. A greater understanding and more theoretical modeling approach is needed to understand the role of directly connected macropores on pathogen transport to subsurface drainage.

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Disciplines
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Role of Directly Connected Macropores on Pathogen Transport to Subsurface Drainage Water

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Introduction

Pathogen contamination of water supplies is now considered one of the top water quality issues in the United States and worldwide. Continual application of livestock manure may contribute to nonpoint source pollution by releasing microbial pathogens including bacteria, virus, and protozoa, through runoff and subsurface drainage water to surface and ground water. Many studies have been conducted in the laboratories and fields to understand the preferential flow through macropores. But no experiments in the field have been conducted to examine the breakthrough curve of pathogen and/or *Escherichia coliform (E.coli)* with directly connected macropores. The objective of this research is to address the transport of pathogens (specifically the indicator organism *E. coli*) through soils, and more specifically the role of macropores in the transport of *E. coli* to subsurface drains. A greater understanding and more theoretical modeling approach is needed to understand the role of directly connected macropores on pathogen transport to subsurface drainage.

Materials and Methods

Field experiments were conducted at Iowa State University Northeast Research Farm, Nashua, IA. The study site has 36 nearly 1-acre plots (190 ft × 220 ft), with fully documented tillage and cropping records for the past 28 years. One set of no-till (NT) and chisel plow (CP) tillage practices was compared in spring 2009 and a different set of NT and CP plots was used for fall 2009 comparison. An area of 100 ft ×100 ft with the drainage tile line running in the middle was chosen in each plot for conducting the experiments. A 6-mil thick, 4-ft wide plastic tarp was spread on the ground above the tile line in the CP plots. Identification and quantification of directly connected macropores were done by using smoke injected directly into the drain tile. After that, liquid swine manure (LSM) was injected into the ground at the rate of 150 lb N/acre at a depth of 10 in., before rainfall simulation in all experiments. Bromide was broadcast in the field as a tracer. Rainfall was simulated in the field using a linear-move irrigation system. The irrigation system moved roughly at 95 ft/h with a wetted radius of 30 ft with a total application of approximately 1.8 in./event. Subsurface drainage water samples were taken to analyze the concentrations of *E. coli*. Concentration of *E. coli* and total coliform in soil and water samples were immediately analyzed on-site within 8 hours using semi-automated quantification methods based on standard Methods Most Probable Number model.

Results and Discussion

Spring and fall field experiments were performed in 2009. Concentrated smoke plumes on the soil surface then indicated a direct pathway between the subsurface drain and the soil surface. In the experiment conducted in spring 2009, approximately

0.3 and 0.5 flagged concentration and diffuse macropores/meter were observed in NT and CP, respectively. Those numbers increased to 1.2 and 0.8 in NT and CP, respectively, in the fall experiment. These results indicated the temporal presence of macropores relative to the activity of earthworms.

In the spring 2009 experiment, the higher numbers of water samples having *E. coli* were counted in NT plot, the one with open macropores. Peak concentration was observed during the first hour after irrigation started in NT plots. Peak bromide tracer concentration was also found at the same time with the breakthrough curve (BTC) of *E. coli*. Some of water samples collected in CP had low *E. coli* concentration, between 1-4 MPN/100 ml, and most of them could not detect any *E. coli*.

Several water samples were also collected and analyzed from both plots after more than 80 hours since irrigation started because of a heavy natural rainfall event. At this time, we still could find *E. coli* in water samples collected from NT plots but not detected in the samples collected from tile drainage water from CP plots. In the fall 2009 experiment, the concentrations of *E. coli* in tile drainage water samples was always detected at the higher levels in NT plots. The highest concentration of *E. coli* was found in NT plots at an order of magnitude higher than the value in CP. Fast BTC again was observed in NT within the first hour after irrigation started (Figure 1).

Results from two experiments indicated fast BTC of bromide and *E. coli* through directly connected macropores. These, however, are confirming the prominent role of directly connected macropores in transporting *E. coli* to subsurface drainage water. Thus, LSM application preceding a rainfall event could be a source of pathogen pollution in tile and groundwater.

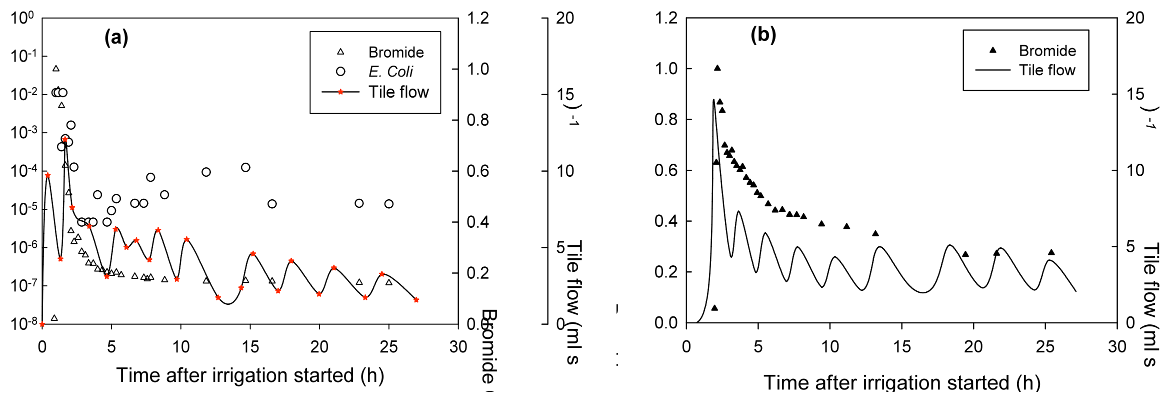

Figure 1. The breakthrough curves of the E. coli, bromide tracer and tile flow: (a) from open directly connected macropore-NT and (b) covered directly connected macropore-CP from the experiment conducted in spring 2009.

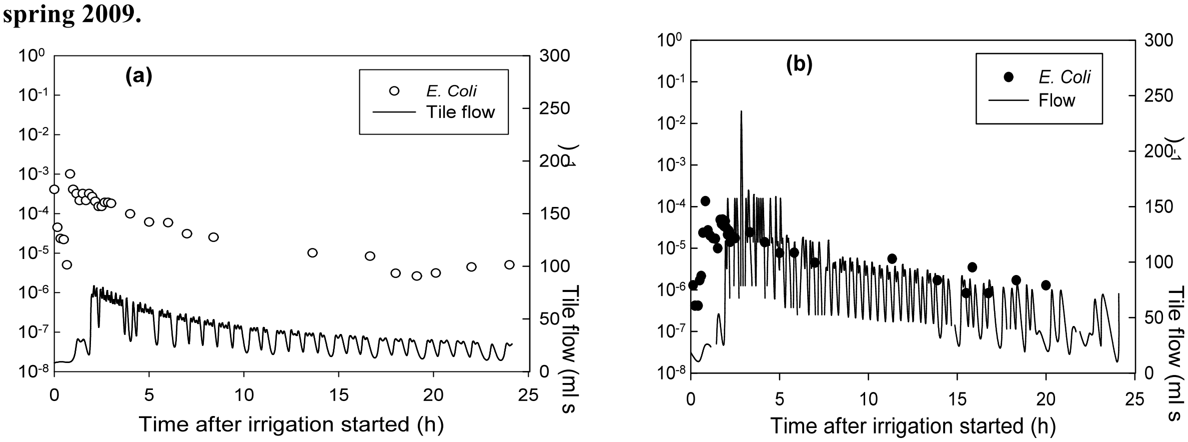

Figure 2. The breakthrough curves of the E. coli and tile flow: (a) from open directly connected macropore-NT and (b) covered directly connected macropore-CP from the experiment conducted in fall 2009.