1997

How Do Bacteria Move Through Soil?

Mark S. Coyne
University of Kentucky, mark.coyne@uky.edu

J. M. Howell
University of Kentucky

R. E. Phillips
University of Kentucky

UNIVERSITY OF KENTUCKY
COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE
Lexington, Kentucky 40546-0091

Department of Agronomy

Soil Science News & Views

Vol. 18, No. 1, 1997

HOW DO BACTERIA MOVE THROUGH SOIL?

M.S. COYNE, J.M. HOWELL, and R.E. PHILLIPS

Introduction

The contamination of water supplies by fecal bacteria is an important water quality issue in Kentucky. Contamination may come from point sources, such as straight pipes depositing raw sewage into streams, or nonpoint sources, such as manure runoff from cropland. A direct cost of contaminating water supplies is the expense that homesteads or water companies incur to chlorinate, filter, and otherwise treat water to make it potable. Indirect costs are the time lost to illness from drinking inadequately treated water, slower weight gain in livestock drinking contaminated water, and the degradation of aquatic habitats.

Many Kentuckians obtain their potable water from ground water. We depend on soil to filter and purify wastes and waste water that are land-applied before they affect ground water. However, in central Kentucky, we have observed a direct relationship between grazing cattle in pasture fields and fecal bacteria in shallow wells and wet weather (breakout) springs. To understand how these water supplies become contaminated by fecal organisms, we decided to first study how fecal bacteria moved through soil. With this understanding, we could test various control methods. We specifically looked at fecal coliforms in this report, since they are the bacteria used to indicate potential fecal contamination in water quality assessment.

specifically looked at fecal coliforms in this report, since they are the bacteria used to indicate potential fecal contamination in water quality assessment.

Methods

We extracted intact soil blocks (13 x 13 x 13 inches) from two soils: a Nolin silt loam and a Lowell silt loam. They were placed on a collection chamber that partitioned leachate into 100 individual sections (10 x 10). This let us map where water and bacteria exited the blocks. Although the blocks were too shallow to realistically assess the depth of fecal bacteria movement in the field, they were large enough so that we could examine the pattern of bacteria movement in a representative mass of undisturbed soil.

Before each experiment, we centered about one half pound of fresh dairy manure (about a tenth of a pound dry weight) on top of a soil block and shaped it to resemble a voided dung deposit that covered 38% of the soil block surface. Each deposit had approximately 5 billion fecal coliforms. We used a laboratory rainfall simulator to rain on the soil blocks at a rate of about 1 inch per hour to cause leaching. Leachate was periodically collected from the 100 individual sections beneath the soil block, and analyzed for total water flow and fecal coliform concentration (the background contamination was not detectable).

Results and Discussion

The saturated hydraulic conductivity of the Lowell soil was 0.3 inch/hour. Leachate was collected in most sections beneath the block (Figure 1) but 20 sections in it accounted for about 60% of the leached water. In contrast, the Nolin soil had a saturated hydraulic conductivity 3 times greater (1 inch/hour) and 20 sections accounted for nearly 100% of the total leachate; these sections were widely distributed (Figure 2).

In both soil blocks, the 20 most rapidly flowing sections accounted for almost 100% of the fecal coliforms that leached. In the Lowell soil, these sections were immediately below the manure deposit (Figure 1) and one section alone accounted for almost 40% of the fecal coliforms. In the Nolin soil, fecal bacteria followed the same distribution pattern as leachate (Figure 2) and 55% of the coliforms that leached were in just one section.

Far more fecal coliforms were trapped in the soil, usually within the first few inches, than were transported through it, however. The fecal coliforms collected in leachate only accounted for 0.01% of the total fecal coliforms in the Lowell soil and 0.1% in the Nolin soil.

In both soils, fecal coliform concentrations steadily increased with time even though the flow through each soil remained constant. After just 1.2 inches of rain was applied, fecal coliform concentrations in the Lowell soil ranged between 2 and 34 fecal coliforms/100 ml. In the Nolin soil, there were 15 to 680 fecal coliforms/100 ml depending on the section we examined. For comparison, the potable water standard in Kentucky is <1 fecal coliform/100 ml and the primary water contact standard (bathing and swimming water) is 200 fecal coliforms/100 ml.

Conclusions

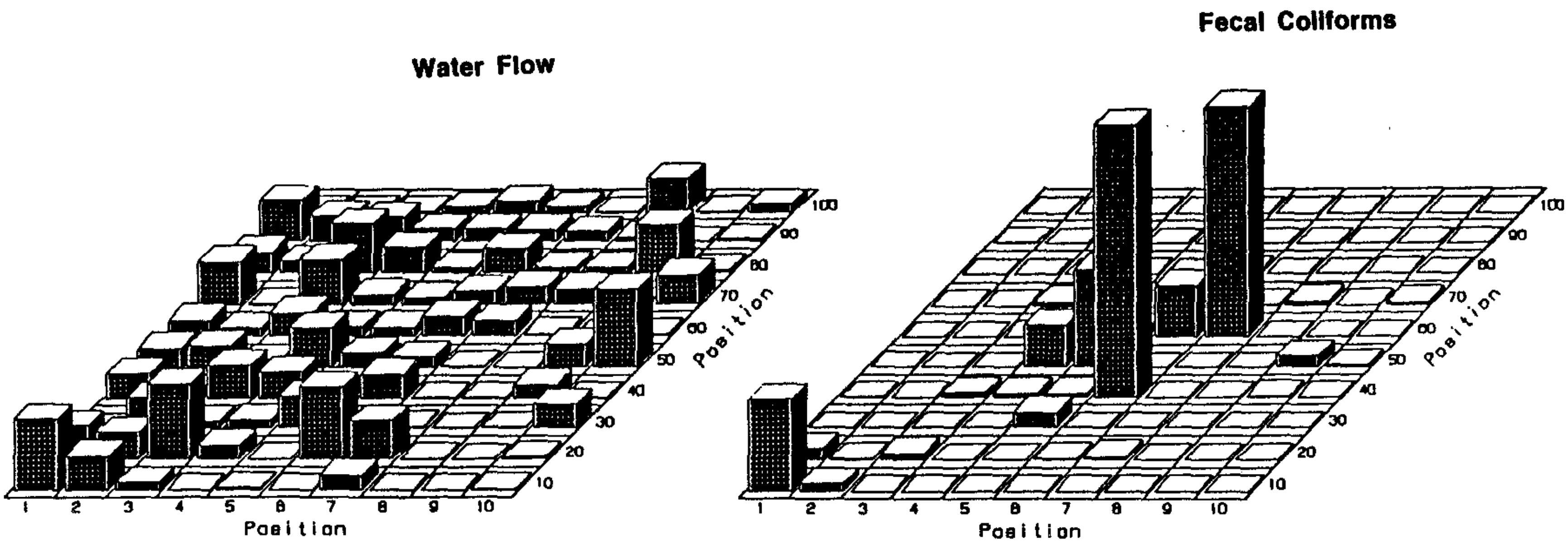
Fecal coliform concentrations in excess of water quality standards rapidly leached through soil blocks with freshly applied dung deposits. The bacteria moved through the most rapidly flowing pores of these soils. The Lowell soil had the lowest saturated hydraulic conductivity, the most evenly distributed water flow, and the lowest fecal coliform concentrations in leachate. The Nolin soil, which had greater saturated hydraulic conductivity and several high-flowing pores, also had the highest fecal coliform concentrations in leachate and transmitted more of the total fecal coliforms from the manure deposit.

Given the many fecal coliforms in leachate from a single manure deposit, and the number of manure deposits typically found on grazed land, it is obvious why wet weather springs and shallow wells underlying pasture lands frequently exceed water quality standards. While the greatest bacterial filtration occurs at or near the soil surface, bacteria moving past this zone can be transported to whatever depth that pores are continuous. The potential for bacteria movement depends on soil characteristics such as soil structure, and will affect ground water to different extents depending on rainfall intensity and duration, and the depth of soil to ground water. The risk it represents for water supplies is presently unknown. Our current challenge is to assess that risk and develop management recommendations to reduce it.

Kenneth L. Wells

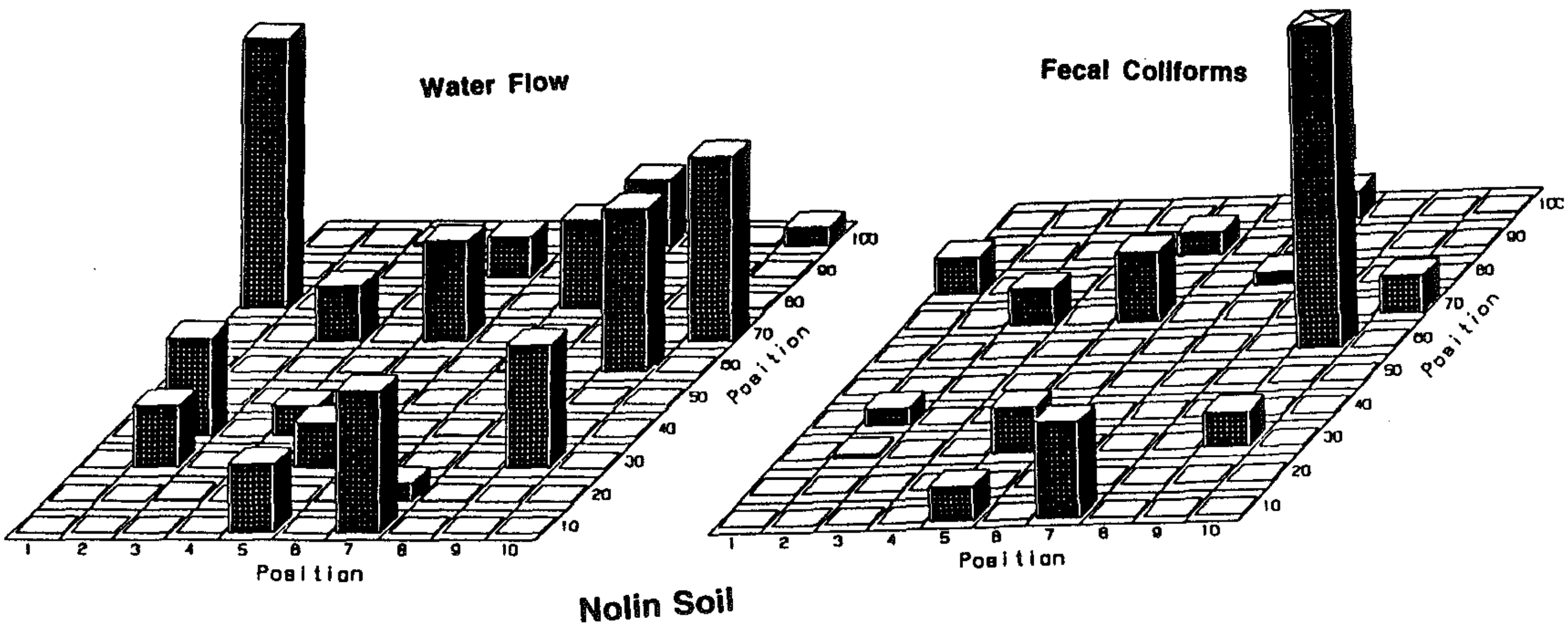
Extension Soils Specialist

Figure 1. The distribution of leachate and fecal coliforms at the bottom of a 13 inch block of Lowell silt loam. The height of the bars is proportional to the % of total flow or fecal coliforms.



Lowell Soil

Figure 2. The distribution of leachate and fecal coliforms at the bottom of a 13 inch block of Nolin silt loam. The height of the bars is proportional to the % of total flow or fecal coliforms.



COOPERATIVE EXTENSION SERVICE
U.S. DEPARTMENT OF AGRICULTURE
UNIVERSITY OF KENTUCKY
COLLEGE OF AGRICULTURE
LEXINGTON, KENTUCKY 40546

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

AN EQUAL OPPORTUNITY EMPLOYER

No. BULK RATE
POSTAGE & FEES PAID
USDA
PERMIT G268