Report for 2005TN16B: Macropores and Colloids: Their Influence on the Quantity and Quality of Recharge

Publications

- Dissertations:
    - Garrett, Tara, J., 2005, Perferential Flow and Colloids: Their Influence on the Transport of Phosphorous, "MS Thesis", Department of Biosystem Engineering and Soil Science, College of Agriculture, The University of Tennessee, Knoxville, TN., pp 108.

Report Follows

Problem and Research Objective:

Although Tennessee is water-rich compared to many states, it is still facing the prospect of shortages in both surface and ground water. Due to population growth and water mining, the value of water resources will only continue to grow. Proper management of water resources requires knowledge regarding the recharge rate of aquifers, and the quality of the water recharging the aquifers and streams. Historically, infiltration has been modeled using simple one-dimensional methods, such as the Green-Ampt infiltration model**.** These methods often underestimate the recharge rate and the risk of infiltrating pollution because they do not include preferential flow, which can be defined as the transport of a portion of water at a much higher rate than the mean velocity. On a microscopic scale, such variation of velocity can be adequately described with a dispersion term. At the macroscopic scale, the variation of flow is more difficult to predict and model.

Preferential flow is often due to macropores, which are continuous pathways through a soil that commonly result from old root canals, earthworms, burrows, insects, or animals. If free water enters the macropores, it flows rapidly downward due to gravity. The macropores are often large enough, such that capillary forces are insignificant. The Reynolds number for macropore flow typically exceeds the laminar flow range, which precludes the use of Darcy's Law to predict its movement. Soil fractures are another source of macroscopic preferential flow, in that the water velocities within the fractures often exceed the laminar range. Fractures can be created during or shortly after deposition of the sediment, as the overburden increases. Soils with expansive clays also contribute to preferential flow as clayey soils are prone to shrink and swell according to water content. Preferential flow due to shrink and swell cycles may be intermittent due to the changing aperture of the fractures.

Beyond the affect macropore flow has on infiltration rate, it also plays a major role in the rapid transport of contaminants. USEPA (1996) perceives eutrophication, which is limited mainly by P in fresh water systems, as the predominant water quality issue facing the United States. Typically, P is thought to be a relatively immobile nutrient within porous media. More recently, examples of P transport within soils with extensive macropore flow have been reported. Macropores enable the majority of the reactive soil matrix to be bypassed, minimizing interaction between the infiltrating water solution and the reactive soil particle surfaces. Once these sorption sites along the pore walls are filled, the remaining ions are free to move with only minimal retardation.

Potential water contaminants, such as P, can rapidly travel through the macropores to depths of several meters or more. If colloids are present, the problem is exacerbated since the sorbing contaminants attach themselves to mobile colloids. The use of animal manure as a crop fertilizer poses a potential water pollution problem since it typically provides excessive P (based on N crop requirements). Further, animal manure also contains an abundance of colloids and organic forms of P, which are inherently more mobile than orthophosphate.

Objectives of Research :

The research objectives of this project were to :

(1) determine the influence of preferential flow paths on the transportation of phosphorus (P) through a soil profile.

(2) determine the effect of fertilizer type (inorganic vs. organic) on the transport of P through a soil profile.

(3) determine the effect of colloids on the transport of P through a soil profile.

Research Results and Findings:

Tests from this study included laboratory evaluation of Cl^-, Br^-, P_{tot}, P_{ino}, and P_{org} transport through large, intact soil monoliths under two rainfall intensities. Results from these test provided the following conclusions.

Preferential flow paths enhanced the transport of P through the soil monoliths. Higher concentrations and an early breakthrough of the tracers exiting the columns showed that the amount of P adsorbed by soil particles is reduced by the presence of macropores. High rainfall intensity that creates temporary ponding on the surface and allows water to flow through macropores increases the likelihood that P will be leached through the soil profile. A higher concentration of P was transported rapidly through the monoliths when water was allowed to pond on the soil surface.

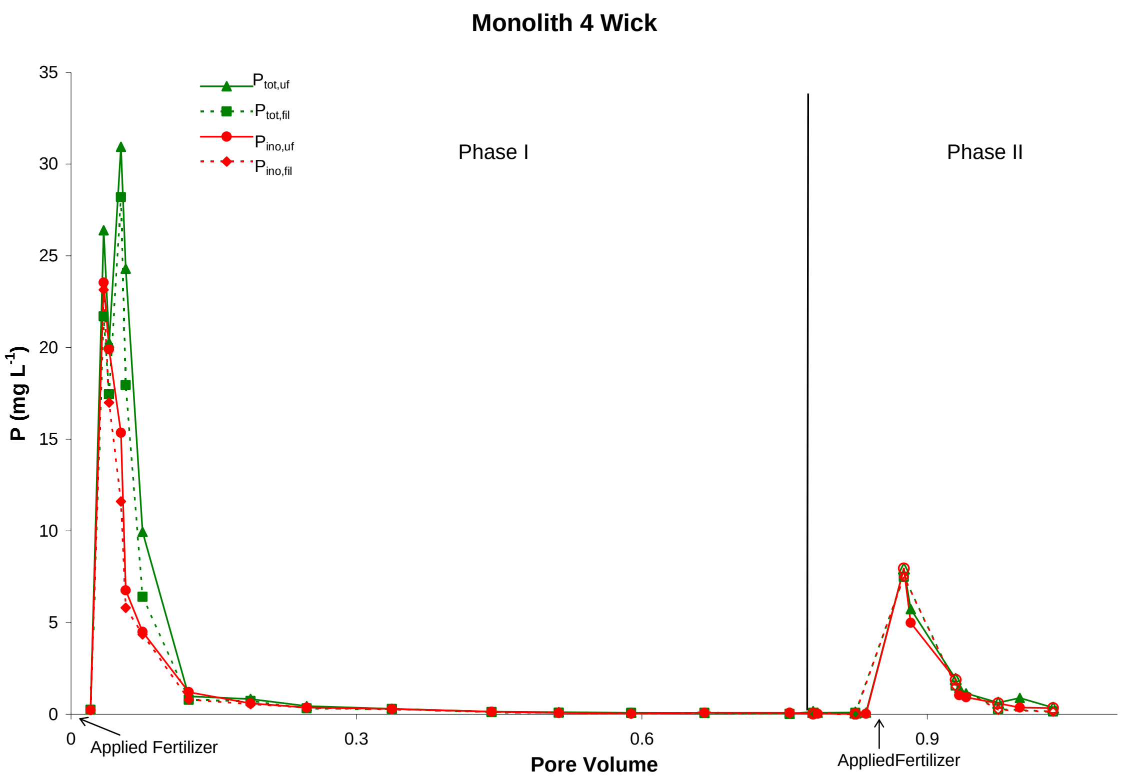

Figure 1. **Concentrations of total unfiltered P ($P_{tot,uf}$), total filtered P ($P_{tot,fil}$), inorganic unfiltered P ($P_{ino,uf}$), and inorganic filtered P ($P_{ino,fil}$) from monolith 4 treated with diammonium phosphate and urea for Phases I and II, wick. Open dots represents the measurements following rainfall application.**

Colloids increased the transport of phosphorous ($P<0.05$). Fertilizer type (organic/inorganic) did not significantly affect the transport of phosphorous ($P>0.05$) through the monoliths.

Summary

P was relatively immobile; except where large preferential flow paths were present. Preferential flow enhanced the mobility of P by allowing it to bypass portions of the soil matrix, leading to potential water quality issues in areas with otherwise similar soil composition. Soils that have large preferential flow paths, receiving continuous poultry litter or any other type of organic fertilizer based on N requirements, may be discharge significant amounts of P.