LEOPOLD CENTER
FOR SUSTAINABLE AGRICULTURE

# Understanding the potential of phosphorus transport to water resources via leaching

Abstract: Improved management of phosphorus (P) from both manure and fertilizer sources is important because of surface water quality concerns. This study considers possible P loss via leaching through the soil and examines the dynamics of the adsorption/extraction process.

## Question & Answer

**Q: To what extent does the lateral movement of water to drain tubes through P-deficient subsoils result in P "extraction" from that water?**

**A:** Despite the possibility of quick vertical movement of P in water percolating down to the water table from the soil surface, P concentrations in tile drainage are much lower than in the percolating water due to subsoil extraction. Based on the estimates of amounts of flow and soil P levels, it is predicted that the subsoil extraction process can be a beneficial factor for several decades, if not longer.

## Background

The general goal of the project is to provide new information and understanding about phosphorus (P) fate and transport in subsoils, and the impact on the potential for P leaching losses, to aid in making correct assessments to protect water quality. As the state develops total maximum daily loads (TMDLs) for its impaired waters, policy makers must have the best science as the basis to choose the correct practices/systems to be implemented to solve P-related problems.

The principal investigators also are involved in a much larger interdisciplinary program to study the impact of manure P management on surface water quality. The Leopold Center-funded project addressed some issues related to subsoil water flow processes that are not being covered by the larger project.

Objectives for this project are:

1. To determine over the short term the rate of and capacity for P removal from water flowing laterally through P-deficient subsoils as it travels to tile drains and
2. To estimate over the long term if the capacity to remove P declines significantly based on measurements (and derived mathematical relationships, possibly as simple as ratios) between P in solution (which can represent leaching water) and P soil test levels in subsoils.

Sampling sump connected to tile drain in foreground; looking up-slope at trench on right, three sampling wells in center.

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**Budget:**
$23,929 for year one
$24,888 for year two

**Approach and methods**

Although some studies show that vertical movement of soluble P with water percolating through the soil profile might result in significant leaching loss, P concentrations in subsurface tile drainage are low, and, as a result, losses also are low (especially in relation to concentrations and losses of soluble P in surface runoff). This raises questions about what process is occurring and whether the process is sustainable.

Researchers hypothesized that while water is moving vertically and quickly from the soil surface down to the water table within the subsoil, it may actually have high P concentrations exceeding 0.50 mg/L. Then, the subsequent slow and lateral movement of that water to a subsurface drain tile allows P-deficient subsoils to adsorb or precipitate (i.e. “extract”) that P before the water reaches and is released by the drain tile.

Investigations were conducted at the ISU Agronomy and Agricultural Engineering Research Center located west of Ames in Boone County. At this field site, water with a very high P concentration (P added to obtain about 9 mg/L) along with a soluble water movement tracer (the bromide anion, Br, added to obtain a concentration of about 100 mg/L), was introduced into the subsoil through a trench parallel to and 10 feet from a tile line. Water sample wells were placed midway between the trench and the tile line. While the water, with the Br tracer, reached the wells and tile drain quickly, P concentrations in the tile drainage increased little, if at all, above the background concentration, verifying the extraction/removal process. Calculations of the amounts of P expected to leach vertically along with the estimated adsorption potential of the subsoils result in the prediction that under currently developing manure management rules, it will be several decades, if not longer, before there are significant increases in P losses in tile drainage.

**Results and discussion**

Water used in this study was subsurface drainage from a large-diameter main collected in a nearby sump. It was analyzed for molybdenum reactive phosphorus (MRP), which is one method to track P concentrations, with an average MRP concentration of 0.006 mg/L. After additions of P and analyses of numerous fillings of the source tank, inflow into the trench showed an average concentration of 8.7 mg/L.

Looking down-slope at trench and solution addition point on left, three sampling wells in center.

MRP concentrations of about 0.010 to 0.035 mg/L in well-water and tile drainage samples were apparent during the water-only input phase. The MRP levels did not show a large and rapid response to the very high P concentrations in the inflow solution—in contrast to the Br data. MRP concentrations in wells on the test site showed an upward trend over time during the 24 days of P addition, and the highest concentration recorded was 1.2 mg/L; for the tile drainage, the highest concentration was 0.125. Following cessation of adding P to the trench, concentrations in the wells generally decreased to less than 0.10 mg/L; the corresponding number for tile drainage was 0.02 mg/L.

Although the Br tracer data clearly indicate that Br in solution added to each trench was reaching the monitoring wells and tile drains in significant amounts, the P data illustrate that the P in solution was not moving as quickly to those sampling locations. Seventy-seven percent of the Br

Source tank for solution of P and tracer (Br) on left; trench on right, three sampling wells in center, and sampling sump connected to tile drain at far end.

Horizontal sampling of the subsoil in the face of a trench following P addition.

was lost, but only 0.38 percent of the P was lost from the plot with tile drainage.  Hence, the P was being removed from the inflowing water by some means; e.g., by adsorption or precipitation.

Tests of soil-available phosphorus at the site showed that available P decreased with increasing distance into the subsoil from the trench walls, except for two well samplings. These data support the MRP in-solution data in that the majority of the added P was not moving with the water in the water table but was being retained elsewhere.

**Conclusions**

There are data from other studies in the Corn Belt to show that water can extract P from fertile surface soils and move quickly down through the soil profile; however, concentrations in water draining from the soils through artificial subsurface drain tubes in Iowa are usually less than 0.05 mg/L. Data from this study show that this results from a combination of physical and chemical processes in the subsoils. When water percolating down from the soil surface through unsaturated soil (at different velocities) reaches the saturated subsoil zone/water table, its velocity is slowed considerably. Except for the small area directly over a drainage tube, that percolating water layers over the existing water table in the saturated zone and begins a much longer (in terms of time and space) trip to a drainage tube. (In Iowa, drain tube spacing generally ranges from 60 to 100 feet). In much of Iowa, this slow, mostly horizontal trip is made through subsoils low or deficient in P. Therefore, with the long retention times and intimate contact with the subsoils, P can be extracted from the laterally flowing water by adsorption and precipitation with cations such as Ca, Mg, Fe, and Al.

In an average year, about 10 cm of water percolates through the soil profile and exits a drain tube, suggesting that at least 0.5 kg P/ha would reach the subsoil each year. How much additional water with P moves down to the subsoil level and is later transpired, and how much of the P in all the percolating water is not extracted by deeper roots and remains to be held by the subsoil is subject to question.

**Impact of results**

The results of this project will affect the continued scrutiny and potential revision of the Iowa P index already used in USDA programs and being considered by the Iowa Department of Natural Resources in the required management of P associated with animal manures.  Because of the information generated in this study, current plans are not to revise the leaching component of the P index but to continue to use the simple but realistic algorithm that was developed.

**Education and outreach**

Information from the project was shared with producers, the public, government agency personnel and other researchers in a number of ways. Baker made presentations at ISU research farm field days at Kanawha and Gilmore City, the ISU Integrated Crop Management Conference, South Dakota drainage meetings in Brookings, and the Iowa-Minnesota Drainage Forum. Government agency staff and scientists were informed about the project in 2003 at the AWRA Specialty Conference in Kansas City and at the ASAE International Meeting in Las Vegas.  Baker also is scheduled to make additional presentations on the results of this research at drainage conferences in Iowa and Ohio in fall 2004.

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