Title: Determining Components for a Phosphorus Interceptor to Reduce Harmful Algal Blooms in the Western Lake Erie Basin

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1. Problem

Harmful algal blooms (HABs) have been observed annually in the western basin of Lake Erie and have increased in size and severity since 2003. *Microcystis aeruginosa* is the dominant species in HABs and produces a hepatotoxin, microcystin, that is harmful to human and environmental health. Elevated levels of microcystin were detected in Toledo's drinking water in August 2014 and caused the city to issue a "do not drink" advisory leaving approximately 500,000 citizens without drinkable tap water.

The occurrence and growth of HABs in Lake Erie is driven by a variety of factors including excessive nutrient transport to surface waters, climate change, and geomorphology of the lake. The presence of excess dissolved reactive phosphorus (DRP) is the primary cause for the growth of HABs. The Maumee River contributes approximately 50% of the phosphorus that reaches Lake Erie with an estimated 85% of the phosphorus derived from agricultural fertilizers and manures. The International Joint Commission set a goal of 40% reduction of phosphorus inputs to Lake Erie from the Maumee River as a potential means to significantly reduce the severity of HAB growth.

Phosphorus in surface water runoff is a combination of particulate and dissolved reactive phosphorus (DRP); whereas, phosphorus derived from tile drainage is almost entirely DRP. We set out to determine a means to capture DRP from tile drainage water that bypasses agricultural field strips. This study investigates the use of calcium-based phosphorus sorbent materials (PSMs) that are incorporated into what we refer to as "nutrient interceptors" with the goal of removing DRP from tile drainage water prior to the water entering drainage ditches and ultimately Lake Erie.

Research Objectives:

(1) Laboratory studies will be used to determine the sorbent-rate, capacity and hydraulic retention time of selected PSMs for use within the nutrient interceptors.
(2) The nutrient interceptors will be tested for removal of DRP from agricultural field drainage water during a rain event to quantify the reduction of DRP per volume water.

2. Methodology

Photos of the experimental set-ups are presented at the end of the written report. A number of PSMs were chosen according to their availability and calcium content and tested to determine the rate of sorption of DRP. Based on the rate of sorption, the most efficient PSM was selected for a laboratory study using flow-through columns and finally field-scale experiments with nutrient interceptors. The chosen PSMs were dried, spent lime obtained from a water treatment plant, limestone gravel, broken and sieved zebra mussel shells in three size fractions (small: < 850 um; medium: between 850 um and 2 mm; large: >2mm), sand collected from the Stranahan arboretum, and lab-grade sand.

Phosphorus Sorption Rate

Phosphorus sorption rate was measured by adding a PSM to a solution of DRP in an Erlenmeyer flask and shaking the sample for 24 hr with periodic measurements. Dried PSM (2 g) was added to 150 mL Erlenmeyer flasks. Each flask then received 30.0 mL of a matrix solution (0.5 mg P/L, 1.0 mg P/L, and 5.0 mg P/L) and placed on the shaker table and shaken at 120 rpm; a 1 mL sample was taken at 1 min, 10 min, 30 min, 60 min, 5 h, and 24 h time periods. The samples were placed in a centrifuge tube and centrifuged for 5 minutes or until the material was fully separated from the solution. The samples were then refrigerated until tested. All PSMs were treated with each matrix solution in triplicate. The samples were analyzed for the concentration of phosphorus using the ascorbic acid colorimetry assay.

Flow-through Column Experiments

Spent lime exhibited the highest rate of phosphorus sorption and was the chosen PSM for flow-through column experiments. Laboratory grade sand was used as a comparative control. For the experiments, the spent lime (5 g) was mixed evenly with laboratory grade sand (95 g), presumably free of phosphorus. This mixture allowed the phosphorus solution to flow through the column unhindered. Six glass columns, 3.8 cm x 20 cm, were placed in a stand and individually connected to a peristaltic pump. The test material was packed into the columns; a phosphorus solution (1.0 mg/L) was pumped to the top of the column and allowed to flow through the PSM. A 45 um filter was placed at the bottom of each column to prevent passage of the sand or water treatment residuals out of the columns and into collection flasks. The phosphorus concentrations in the exiting water solutions were measured at thirty minutes intervals in 5 mL samples.

Flow-through Nutrient Interceptors

The water treatment spent lime exhibited promising sorption capacity using the above controlled laboratory settings. Performance was therefore measured at a scale similar to that present for agriculture drain tile flow. A nutrient interceptor was constructed for this purpose using two 19 L open top buckets, two ½" bulkhead fittings, and a 5 micron industrial filter. Water treatment residuals and laboratory grade sand at a 1:6 volumetric ratio were mixed evenly as above and two kilograms of the mixture were placed into the interceptor. A 0.5-mg/L DRP solution was passed through the interceptor using a 1-meter head for 3.5 minutes; during this time, approximately 11 liters of phosphorus solution flowed through the interceptor at a rate of 3.14 liters/minute. Inflow and outflow samples of solution were taken every 30 seconds in a 10 mL test tube. In total, 8 samples were taken for both inflow and outflow, which were then assayed for phosphorus concentration.

2. Principal Findings and Significance

Phosphorus Sorption Rate

For the majority of PSMs, phosphorus sorption increased over time and at a rate that increased with increasing concentrations within the solutions. The water treatment spent lime achieved maximum sorption within 1 minute of contact with solution. The results for two PSM is depicted in Figure 1: note that sorption with zebra mussel shells is comparatively slower; the spent lime has a faster sorption rate and reaches capacity in less than one minute.

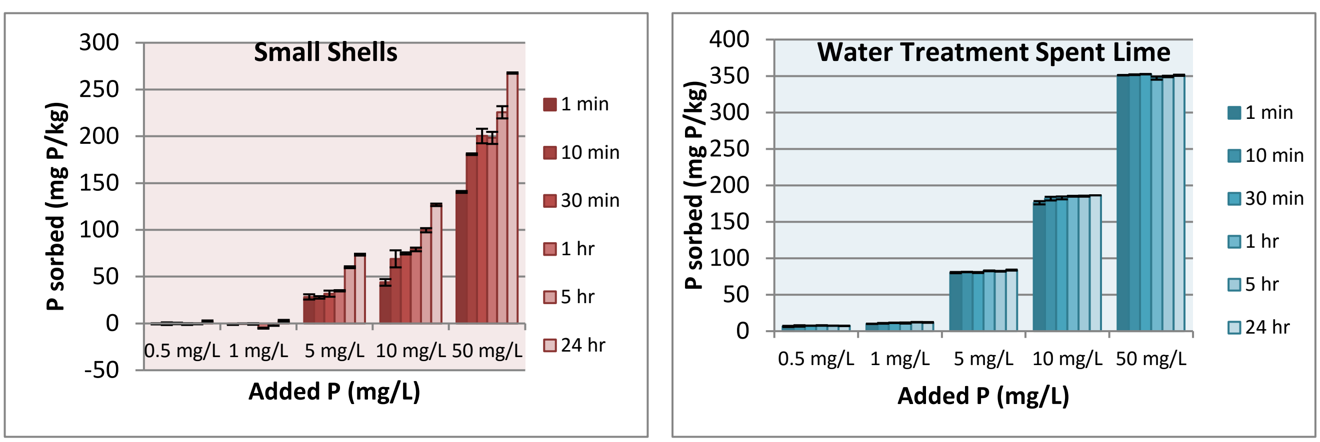

Figure 1. Phosphorus sorption (mg/kg) of small pulverized mussel shells (left) and water treatment spent lime (right) at various phosphorus concentrations and timeframes.

Flow-through Columns

Water treatment spent lime was mixed with sand in a flow-through experiment to determine the sorption capacity of the spent lime. Figure 2 depicts a flow-through data set of phosphorus sorption as a 1.0 mg/L solution of phosphorus flows through a spent lime and sand mixture. Sorption of phosphorus reached a maximum at 0.4 to 0.5 mg P sorbed to 1 gram of PSM. These values for carrying capacity will be utilized to design full scale nutrient interceptors for agricultural drain tiles.

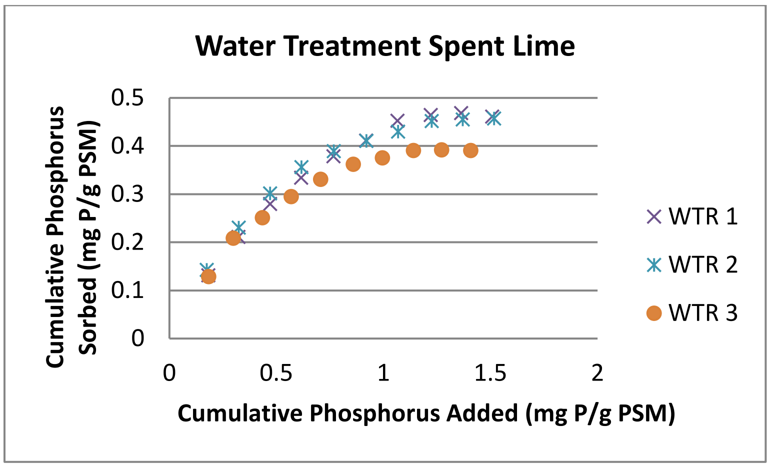

Figure 2. Sorption curve of spent lime in a flow-through experiment.

Flow-through Nutrient Interceptors

To date, the nutrient interceptor has been designed, constructed, and tested. Data have been collected for a preliminary laboratory experiment to ensure that the system was structurally sound. To date, the nutrient interceptor was used to treat tile drainage water for a single replicate using a farm field in the City of Oregon, OH. Data have yet to be analyzed; we will continue to test the effectiveness of the nutrient interceptor in the coming weeks with additional replicates.

Photos

*Flow-through experimental setup

*Flow-through experimental setup and PSM in columns

*Sorption rate experimental setup/shaker table.