Effectiveness of Iron-Enhanced Filtration Techniques in Phosphate Removal from Urban Stormwater

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Introduction

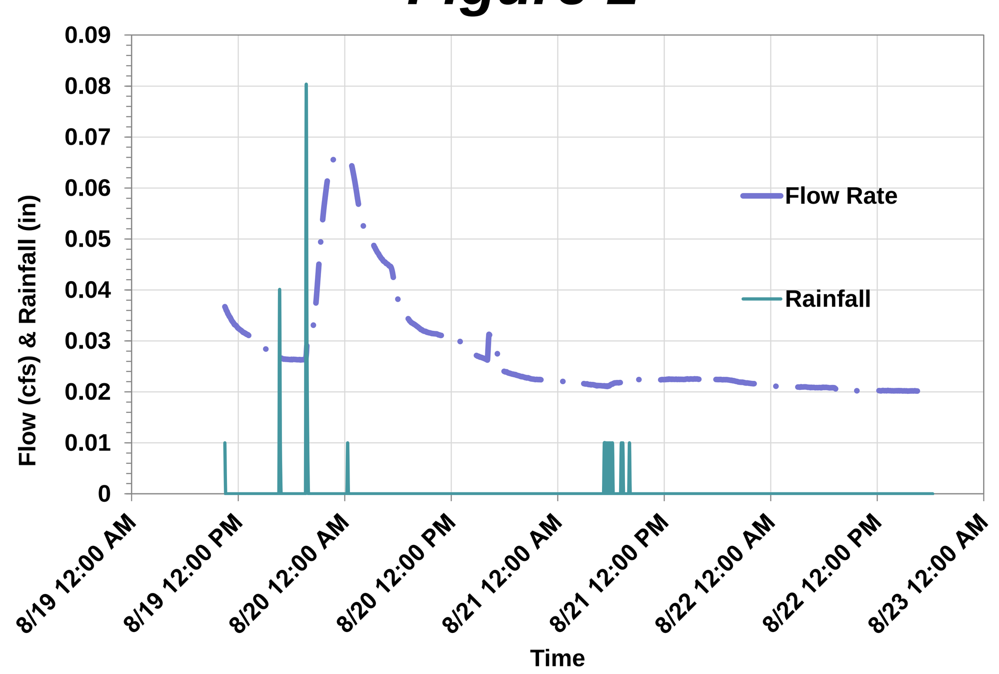
In recent years, phosphorus levels in surface freshwaters have increased dramatically due to excessive urban stormwater runoff loading from impervious surfaces such as driveways, streets, roofs, and parking lots. In a study of phosphorus loading to Lakes Wingra and Mendota in Wisconsin, urban sources contributed 80% of phosphorus loading (Waschbusch et al. 1995). With high phosphorus content in lakes and rivers, eutrophication becomes a significant problem, as phosphorus is often the limiting nutrient in phytoplankton production (Schindler 1977). Often, non-structural management practices can be put in to place to mitigate urban phosphorus loading such as fertilizer and irrigation management, water reclamation, street cleaning and maintenance (South Florida Water Management District 2002); however, to further improve pollutant removal, structural and technological practices can be implemented. One such technology that has been tested in a laboratory setting by Erickson et al. (2007) is the iron-enhanced sand filtration (IESF) method for removal of dissolved phosphorus (or phosphates). The filter media composed of 95% C-33 sand and 5% iron filings (by weight) showed up to 90%? phosphate removal in the batch and column studies. A field installation of the IESF technology has been implemented in the City of Prior Lake, Minnesota. The iron enhanced sand trench, installed on the perimeter of a wet detention basin, treats the basin overflow during wet weather periods. In 2012, Erickson et al. (2012) tested the trench-filter performance by conducting a synthetic runoff test using simulated runoff containing phosphate, and found that filter retained between 29% and 91% of phosphorus; usually the removal was greater than 50%. Since 2012, effectiveness of the filter during natural rainfall events has been monitored.

The objective of this project was to determine the efficiency and effectiveness of using iron-enhanced filtration to lower dissolved phosphorus levels in stormwater. Using this technology, the high phosphorus levels that characterize urban gray-water can be reduced to acceptable levels that will protect our surface water systems from extreme eutrophication.

Methods

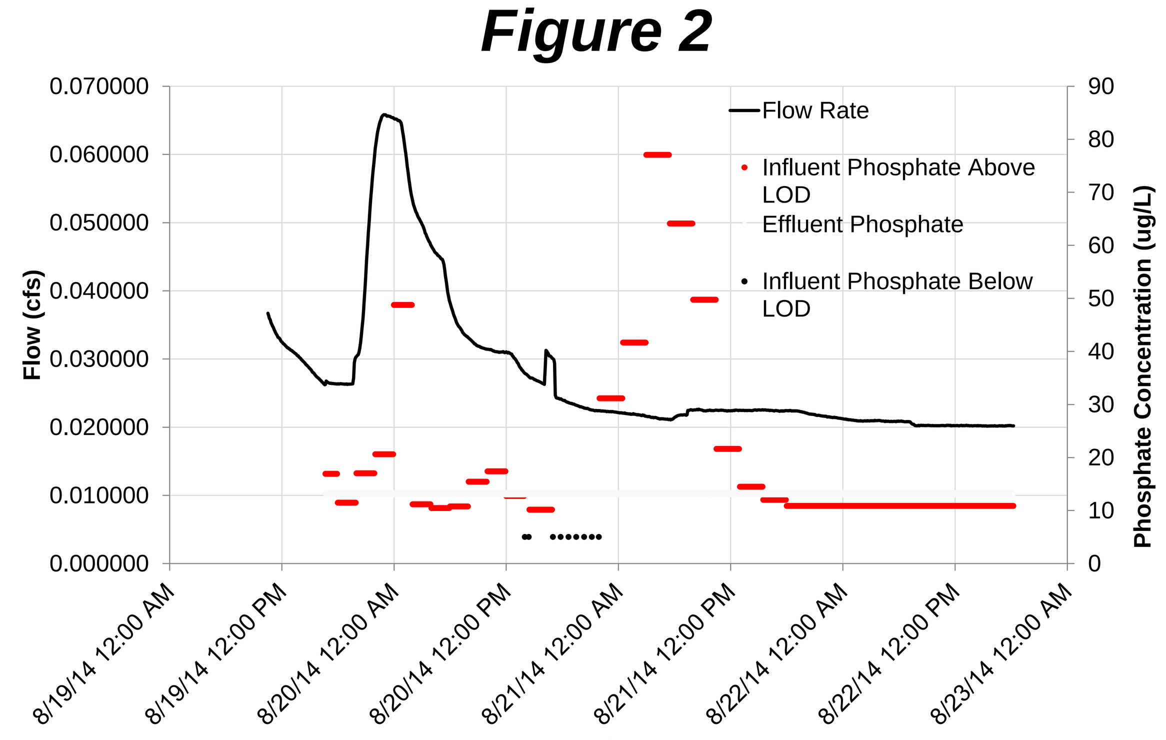
Monitoring at the study site included measuring the rainfall depth, water level in the wet basin, and outflow from the sand filter. The data were recorded in a data logger. Influent (pond outflow) and effluent water (filter outflow) samples were collected during each rainfall event using ISCO samplers. The sampling was triggered for rainfall depths > 0.01 inches. While influent samples were collected on a time based sampling program, the effluent samples were volume-weighted composite samples. See *Figure 1* for a sample data collection from Event 24.

Figure 1



After collection, water samples were transported back to St. Anthony Falls Laboratory, filtered through a 0.45 micron membrane filter to remove particulates, and the filtrate was frozen until analysis. Samples were analyzed for phosphate according to Standard Methods (4500-P Section E Ascorbic acid;(APHA, 1998) using an Lachat analyzer (QuikChem FIA+ 8000 Series) (detection limit = 0.01 mg PO_4^{3-} P/L). *Figure 2* displays the plotted analysis results.

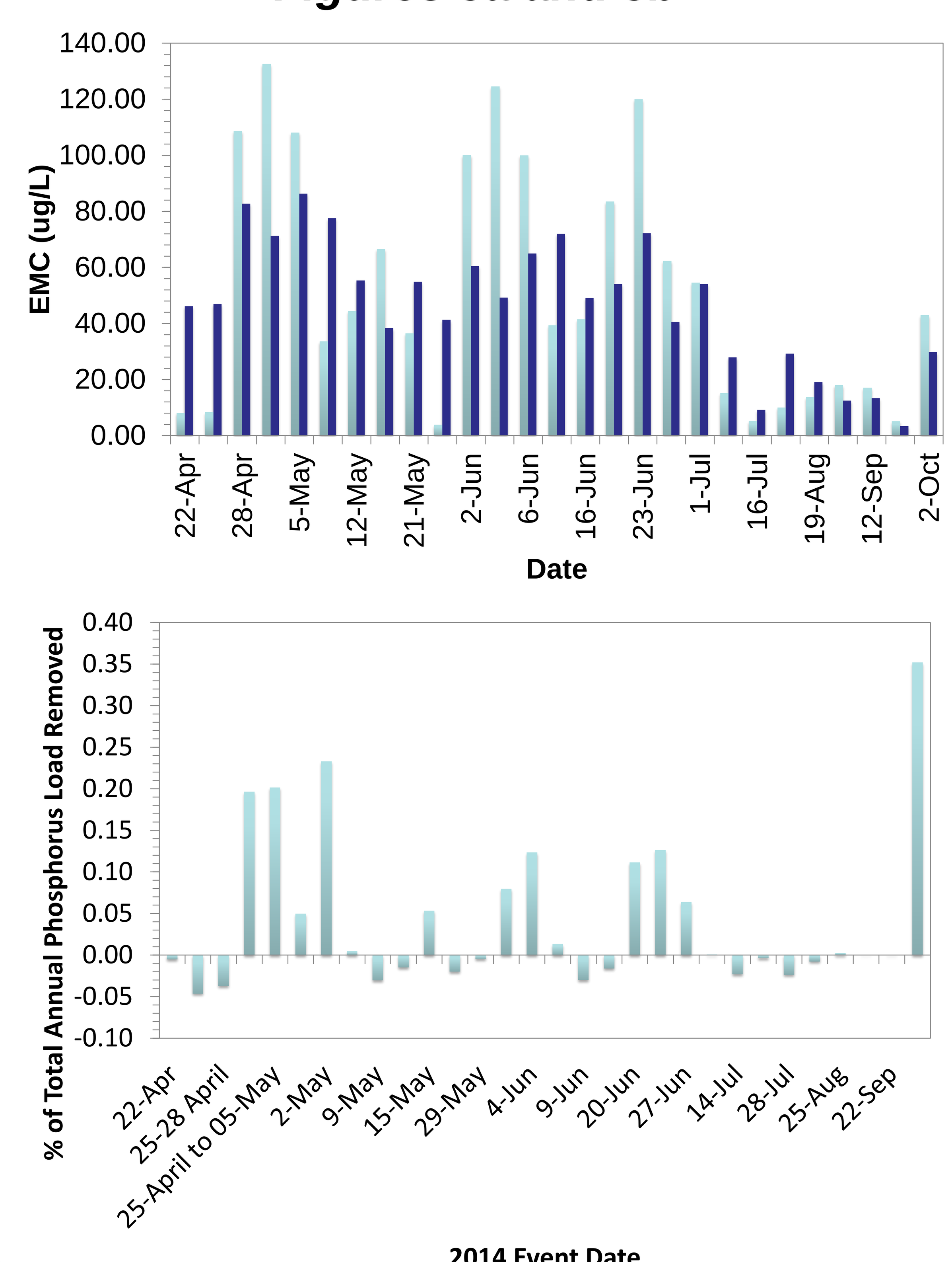
Figure 2



Results

A total of 27 rainfall events were monitored for phosphorus removal from stormwater runoff via the installed iron-sand trench filter installed in Prior Lake, MN. Stormwater from each event runs through the filter, and as iron is oxidized the available phosphorus in the stormwater adsorb to the surface of the iron (Erickson et al., 2012). For each event, summation of mass load and event mean concentrations were calculated. *Figure 3a* shows a comparison of influent and effluent EMCs, and *Figure 3b* shows the % of the annual mass load reduction for each event. A negative phosphorus reduction can be attributed to the wash out of accumulated phosphorus within the trench-filter. If the iron becomes fully saturated with phosphates, there is no more available area for adsorption and the bioavailable phosphorus remains in the effluent and some adsorbed phosphates may leach into the water that passes through the filter.

Figures 3a and 3b



Conclusions

For the events monitored in 2014, the total annual (cumulative input) phosphate load is calculated to be 1.49kg, and the total output phosphate load is 1.14 kg . This means a 23.5% reduction of the annual phosphate mass load occurred through the filter. Mass load reduction was the primary metric used to determine the efficacy of the filter in removing phosphorus from the stormwater. This average is below the average phosphorus retention in the filter that was determined from synthetic runoff and columnar testing done previously (Erickson et al., 2007).

Ultimately, a 23.5% phosphate removal efficiency is not a successful removal rate for the iron-sand trench filter, as the expected removal inferred from the columnar testing was expected to be approximately 70%. In an effort to improve the phosphate removal, maintenance on the filter was performed in August 2014, which entailed mixing in new sand, churning old sand and iron filings. Following this maintenance, the filter appears to perform consistently well with an average removal of 30.3% for the last 4 events. From these results, we concluded that in order to efficiently remove phosphorus from urban stormwater runoff maintenance should be performed annually or biennially to keep the filter functioning properly.

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