Draft Report

Phosphorus Removal using Dead End Membrane Filtration

Prepared for

Michigan State University

April 2011

Contents

Introduction

Tertiary treatment is being implemented at many wastewater treatment facilities to meet stringent discharge requirements. Discharge levels for coliform bacteria and nutrients will continue to be lowered to maintain discharge limitations based on NPDES permits as well as meet best available technology requirements. Of particular interest is phosphorus in wastewater effluent which typically enhances eutrophication in natural systems and can severely impact the designated use of receiving waters. Phosphorus removal to 0.05 ppm total phosphorus is generally achievable with best available technology for traditional wastewater treatment. Typical tertiary treatment includes deep sand filters, membrane filters, and cloth media filters. The wastewater treatment at the East Lansing Wastewater Treatment Plant (WWTP) consists of primary screening, secondary treatment with activated sludge, secondary clarification, addition of ferrous chloride(for phosphorus control), chlorination, tertiary filtration in deep sand beds, dechlorination and discharge to the Grand River.

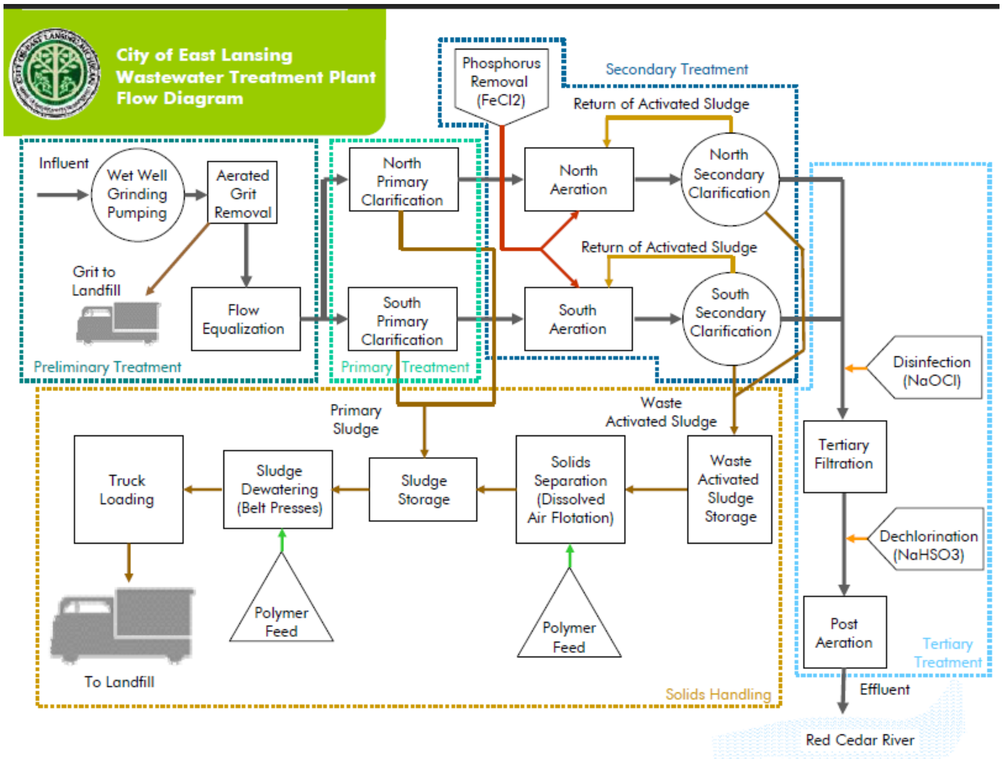
Background

While deep sand filtration can be effective in tertiary treatment, this technology requires a large amount of time and space to function. In addition, deep sand filters are not effective in treating less common wastewater pollutants such as pharmaceuticals. Membrane filtration technology has proved to be effective at removal of typical wastewater pollutants. Membrane technology requires less space than deep bed sand filters and more energy. In addition, operation and maintenance of membrane filters is typically greater than deep bed sand filters. This report evaluates the use of dead end membrane filtration on secondary effluent for particulate phosphorus removal and compares the effluent water quality with the discharge effluent water quality from the East Lansing WWTP.

East Lansing WWTP

The East Lansing Wastewater Treatment Facility can provide treatment for an average design flow capacity of 18.75 million gallons per day (MGD). Information presented in this section was obtained from the East Lansing WWTP website. The average wastewater flow (influent) is 13.40 MGD. Treatment processes include aerated grit removal, flow equalization, primary clarification, course bubble air diffusers to supply oxygen to the activated biological solids, secondary clarification, disinfection, rapid sand filtration, dechlorination, and post filtration aeration. A flow diagram of the treatment process is shown in Figure 1.

FIGURE 1.
East Lansing Wastewater Treatment Flow Diagram



Membrane Filters

Membrane filters use different membrane media to filter wastewater. Numerous membrane media are available and range in pore size and filtration capacities. Membrane filters use a pressure gradient to force wastewater through the membrane, leaving contaminants behind. As pore size decreases, the energy required to force the wastewater through the media increases. Different types of membranes are used for different filtering capacities. Membranes are used for microfiltration, ultrafiltration, nanofiltration and reverse osmosis.. Siemens and GE manufacture membrane filters for tertiary treatment. The membrane filters are backwashed when the head loss over a filter indicates the membrane has reached its treatment capacity. The advantages and disadvantages of membrane filters are as follows:

- Advantages
  - Small footprint
  - Installation could be modular for future expansion
  - Can achieve a very high quality reuse water
- Disadvantages
  - Higher cost
  - High energy consumption
  - Additional ancillary equipment, requires building space

Materials and Methods

Nylon membrane filters were purchased from Sterlitech Corporation (P/N NY01SP). Filters are 0.1 um with 76mm diameter. Wastewater was obtained from the East Lansing WWTP directly from the secondary clarifiers. Chlorine and ferric chloride had been added to the wastewater upstream of the collection point.

Scissors were used to shape filters before placing in a 180 mL Amicon Model 8200 filtration device. Wastewater was placed in the pressure tank and a sample was taken from the pressure tank to represent the influent concentration. The dead end filter was connected to the pressure tank and a 1 L beaker placed on an automatic scale. Pressure was supplied by a nitrogen tank as described in Munir, 2006. Wastewater traveled from the pressure tank through the membrane filter for collection in a 1L beaker. Wastewater was weighed every ten seconds from the automatic scale and collected in an excel spreadsheet using a computer and LabView software. Experiments were conducted in triplicate at 15, 30 and 40 psi until a final volume of 300mL of effluent was obtained from each run. Samples were taken directly from the 1L beaker after filtration to represent the effluent concentration.

Total and soluble phosphorus were analyzed using ion chromatography in a Dionex ICS-5000. A concentrator column was used with the anion column to determine phosphate concentrations. Samples were digested using SM 4500-P H. and processed with ion chromatography using a Dionex ICS-5000 to determine total phosphorus concentrations. Table 1 shows the analytical methods used for each analysis and the respective holding times.

TABLE 1
Laboratory Analytical Methods, Sample Containers, Preservatives, and Holding Time Criteria

Laboratory Analysis	Analytical Method(s)a	Preservative	Unit of Measure	Holding Time
Ortho phosphorus (P)	SM 4500- P / EPA 365	None		48 hours
Total phosphorus (TP)	SM 4500-P / EPA 365	H_2SO_4, pH<2	mg/l	28 days

Data Analysis

Average total phosphorus and orthophosphate were determined for each triplicate sample and reported with the standard deviation.

Calibration Curve

A 10 point calibration curve was used to estimate the orthophosphorus and total phosphorus concentrations. The MDL for orthophosphorus was 0.092 +/- 0.003 mg/L with 95 percent confidence. The orthophosphorus correlation coefficient is 99.9 percent. The standard curve for orthophosphorus is shown in Figure 2.

FIGURE 2
Orthophosphorus Standard Curve

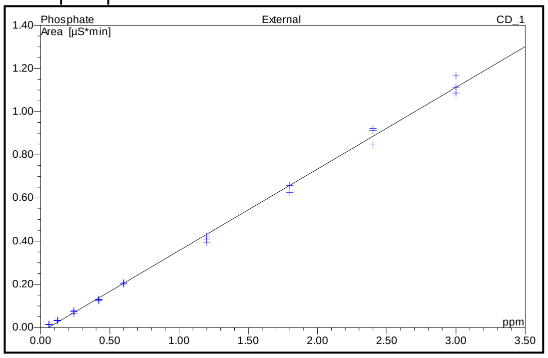
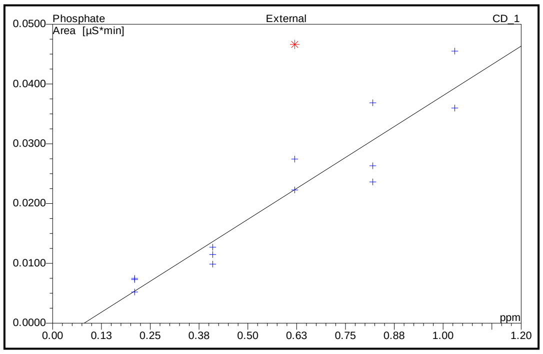


FIGURE 3
Total Phosphorus Standard Curve



The MDL for total phosphorus was 0.24 +/- 0.03 mg/L with 95 percent confidence. The standard curve for total phosphorus is shown in Figure 3. The total phosphorus correlation coefficient was 94.7 percent, 5.1% lower than the orthophosphorus due to the nature of the digestion process.

Results

Filter time, peak flux and final flux varied based on the pressure of the system. Time to reach 300 mL filtrate was minimized while the peak flux and the final flux were maximized at 40 psi. The results for the time to reach 300 mL, peak flux and final flux for each pressure are shown in Table2.

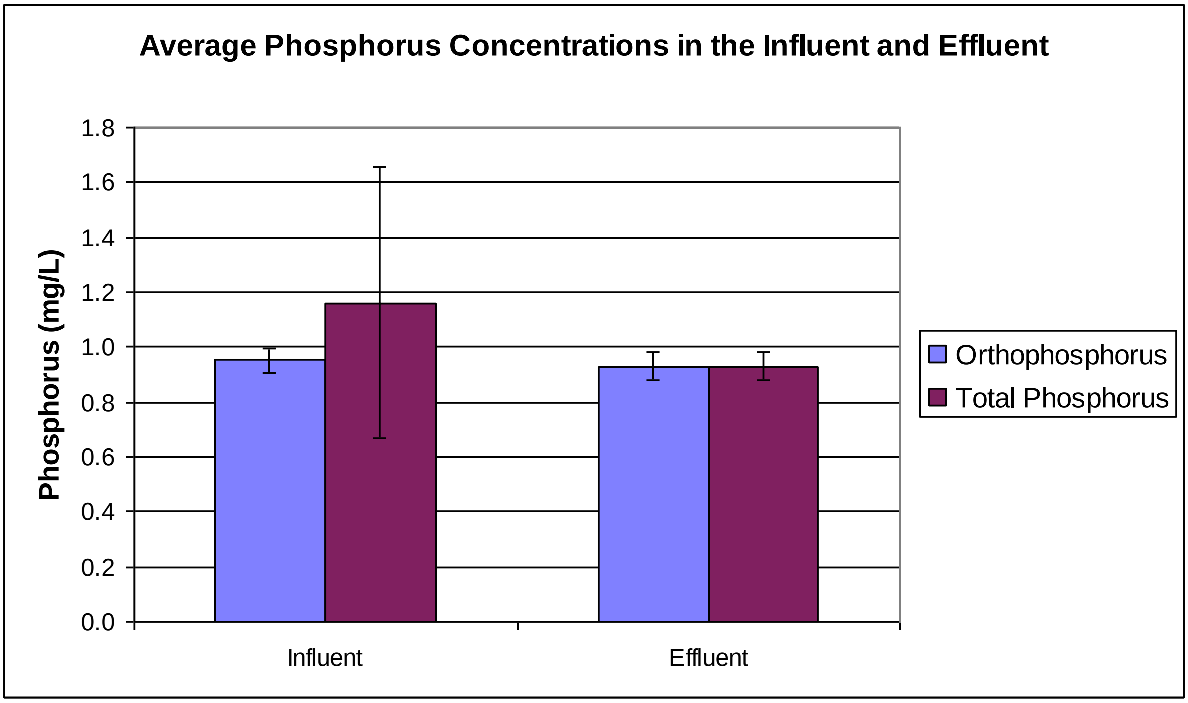
TABLE 2
Flux and Filter Time at Different Pressures

	Time to Filter 300 mL (seconds)	**Peak Flux** (mL/sec)	**Final Flux** (mL/sec)
15psi	1470 +/-16	0.75+/-0.03	0.1+/-0.01
30psi	784 +/-50	1.15+/-0.07	0.15+/-0.02
40psi	447 +/-12	1.48+/-0.02	0.30+/-0.03

As expected, the peak and final flux increased with increase in pressure while the time to filter 300 mL decreased with decrease in pressure.

Wastewater effluent from the East Lansing WWTP was tested and determined to have 0.87 mg/L orthophosphorus (orthoP) and 6.9 mg/L total phosphorus (TP) representing 12.7 percent of the phosphorus being orthoP. Sample influent phosphorus concentrations taken from the secondary clarifier show that the majority of phosphorus detected was orthoP with less than 18.2 percent being TP. Average phosphorus concentration in the influent and effluent are shown in Figure 4.

FIGURE 4
Average Phosphorus Concentration in the Influent and Effluent

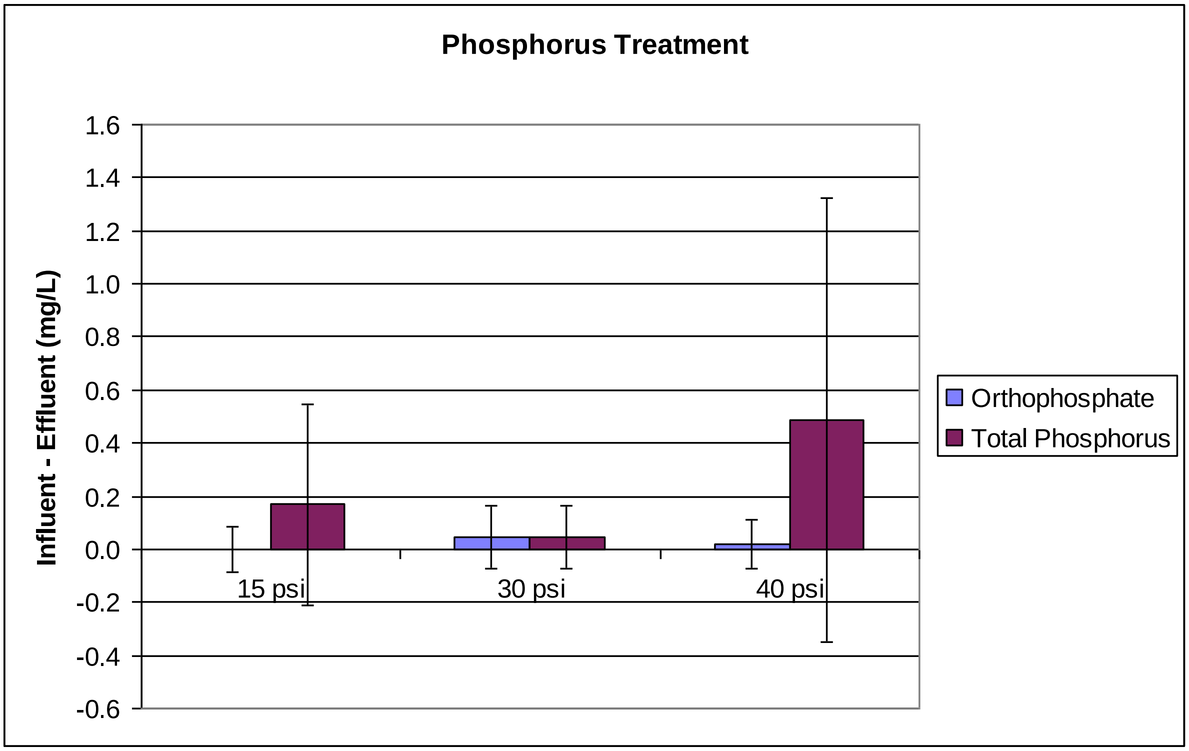


There was a high variability of total phosphorus in the influent samples with only two samples showing particulate phosphorus. This is most likely due to settling of particulate matter during storage. 100 percent of the phosphorus detected in the effluent samples was orthophosphorus, indicating that membrane filtration removed 100 percent of particulate phosphorus.

Discussion

Total phosphorus and orthophosphorus treatment efficiency was evaluated by subtracting the effluent from the influent concentrations. There was very little change from the influent and effluent orthophosphorus indicating that the soluble phosphorus was not retained by the 0.1um nylon filter. Particulate phosphorus that was detected in the influent was reduced to non detectable levels in the effluent after filtration. Phosphorus treatment efficiencies for orthophosphate and total phosphorus are shown in Figure 5.

FIGURE 5.
Phosphorus Treatment



Particulate phosphorus was found in two influent samples, 15 psi B and 40 psi C. While it appears that total phosphorus treatment efficiency is greatest for the 40 psi pressure, that is because the particulate phosphorus concentration in 40 psi C run was higher than the particulate phosphorus found in any other influent sample. The 0.1 um nylon membrane was 100 percent effective at removing particulate phosphorus regaurdless of the pressure of the system and not effective in removing orthophosphorus.

It appears that the tertiary sand filters may be adding additional particulate phosphorus to the final effluent at the East Lansing WWTP. Water quality data taken from the secondary clarifiers indicates that the particulate phosphorus concentration is less than 19 percent of the total phosphrous concentration while the particulate phosphorus concentration of the tertiary effluent from the WWTP was 87 percent particulate phosphorus. In addition, the average total phosphorus concentration from the secondary clarifiers was less than 1.2 mg/L while the total phosphorus concentration in the tertiary effluent from the WWTP is 6.9 mg/L. It is possible that the sample obtained from the secondary filter and the tertiary effluent are not representative of the system at the East Lansing WWTP or a significant microbial population could be growing in the sand filter. As chlorine is added to the effluent prior to tertiary filtration, it appears that the samples obtained from the WWTP are not representative.

Conclusion

In conclusion, the addition of a membrane filter would greatly increase the phosphorus treatment efficiency at the East Lansing WWTP. Sample data indicates that orthophosphorus concentrations are less than 1.2 mg/L indicating an 80 percent reduction in phosphorus concentrations can be obtained with membrane filtration.