Removal of Human Viruses via Membrane Bioreactors

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Abstract

With a finite supply of potable water, the growth of urban populations has significantly increased demand on already stressed water resources. Looking to alleviate present and future strains on water supplies, scientists and engineers alike have delved into designing increasingly efficient water treatment systems, especially for wastewater. Ideally, these research goals revolve around a future based in sustainable, potable reuse of wastewater.

Focusing on Membrane Bioreactor (MBR) systems, this summer research concentrates on understanding pathogenic virus removal. Objectively, this research hopes to: quantify pathogenic removal in full-scale systems (utilizing American Canyon Wastewater Treatment Facility as the primary sampling site – MBR site), examine virus removal contributions of membrane cake layer and suspended solids respectively, and explore the role of pathogenic virus decay present in the MBR system.

A bench scale system is required to allow for increased variable control and easier understanding of MBR removal mechanisms. The design, assembly, and testing of the bench scale MBR became the first half of the summers focus. This portion of the research primarily focuses on determining which components are required in the system, and what the individual part parameters must be to correspond with the preferred design parameters. To do this, extensive design iterations were necessary in the three major components of the bench scale reactor: influent flow, effluent flow, and aeration. Upon completion of the 2013 summer REU program design iterations were completed for membrane epoxy methods, aeration supply, influent flow, and effluent flow, along with basic module and reactor design. This work culminated in a final design schematic identifying parts ready for procurement and assembly. When finished the bench MBR system will allow for specific testing of pathogenic removal rates and will shed light on functional strengths and weakness of the MBR system as the quest for reinventing urban water systems continues.

The second half of the summer research concentrated on the processing of field samples and developing new measurement techniques in coliphage and particle counting. After taking field samples at American Canyon Wastewater Treatment Plant the samples were concentrated into smaller volumes in order to quantify the amount of viruses present. Primarily working with permeate, the samples were introduced to eluting and then flocculating procedures to concentrate the collected viruses from a starting volume of 200 liters into a final concentrated volume of approximately 25 ml. Each concentrated 25 ml sample was then run through a qPCR to quantify the viruses present.

After concentrating the individual field samples it is possible to run coliphage. Coliphage is a type of bacteriophage that infects E. coli and is used as an indicator virus based in culturing methods. This summer research project implemented F-amp coliphage which required a host to be grown before being infected by the virus. The end of the summer emphasized developing successful culturing techniques while determining the correct types of dilutions for each sample. Preliminary test one, Fig. 1,

shows progress in determining which dilutions are ideal for each sample. Based on this research a correct dilution should be around 10-100 plaques per plate and is most commonly seen on undiluted, 10^-1 dilutions, and 10^-2 dilutions samples. Moving forward coliphage tests will be run with those individual dilutions.

Finally, this research also began employing particle counts directly after the membrane washing procedure in the permeate. This process involves taking particle measurements ranging from 2-15 micrometers every minute for three hours directly after a wash. Following this procedure can help determine how particle removal progresses after the cleaning cycle ends and cake layer begins to develop. Fig. 2 demonstrates the first particle test's data and indicates that particle removal increases significantly as filtration continues after cleaning. The highest quantities of particles pass directly after the membranes are cleansed of the cake layer and decreases as the cake layer redevelops. Additional particle spikes can be noted following scheduled membrane relaxations. These spikes further support the importance of the cake layer since relaxation indicates the stopping of the applied filtration vacuum allowing the cake layer to fall from the membranes. This action resulted in the increase of the amount of particles measured in the permeate and demonstrates that the cake layer provides a form of secondary filtration.

SAMPLE LOCATION	undiluted	10^-1	10^-2	10^-3	10^-4	10^-5
Influent	Too many	✓	✓	< 10	none	none
Return Sludge	✓	✓	✓	none	none	none
Permeate	✓	✓	< 10	none	none	none
Mixed Liquor Solids	✓	✓	✓	none	none	none
Mixed Liquor Liquids	✓	✓	✓	none	none	none

Figure 1. Coliphage Dilution Tests

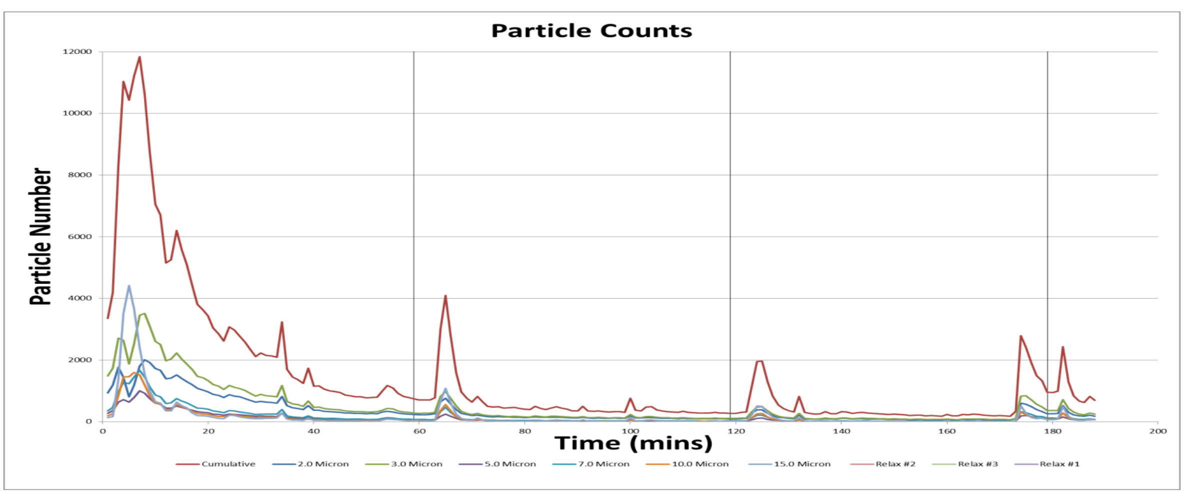

Figure 2. Particle Count Data