Energy Optimization Strategies in a Sequencing Batch Membrane Bioreactor

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SUMMARY
Decentralized wastewater treatment systems can serve small communities and supply water suitable for reuse applications such as irrigation. An example of decentralized treatment is a sequencing batch membrane bioreactor (SBMBR), which treats small batches of wastewater and implements membrane filtration as a final treatment step. While treated effluent from the SBMBR is very high quality, high operating costs are a significant drawback. This study examines energy optimization strategies and operating costs of an SBMBR designed by Aqua-Aerobic Systems that treats water from Mines Park, a student apartment complex affiliated with Colorado School of Mines.

INTRODUCTION
The SBMBR used in this study is a hybrid system that integrates a sequencing batch reactor (SBR) with a membrane bioreactor (MBR). The SBR sequentially treats batches of wastewater with two bioreactors. Discharged water from the SBR is then filtered with hollow fiber membranes in an MBR as a final treatment step. This filtration process is called permeation. A schematic of the system is shown in the figure below.

Aeration is the highest operating cost for the SBMBR. Both the bioreactors and membrane tank aerate, which is essential to remove nutrients and prevent membrane pores from clogging (fouling). Two optimization tests related to aeration were conducted, one in the bioreactor and another in the membrane tank.

• First, different mixing and aeration conditions were tested to compare each configuration’s rate of oxygen transfer to the bioreactor. Data from these tests is useful for comparing and optimizing the different aeration systems.
• Second, an experiment was conducted to observe if pausing permeation (membrane relaxation) might allow aeration to better clean fouled membranes. During permeation, a cake layer of particles builds up on the membrane surface and fouls the membrane (Figure 2). Fouling results in a greater pressure difference across the membrane, which is defined as transmembrane pressure (TMP). As TMP increases, the permeate pump requires more energy to maintain constant flow. Literature suggests that membrane relaxation reduces TMP buildup over time by enabling the cake layer to more easily break apart.

RESULTS AND DISCUSSION

Oxygen Transfer Results
Upgrading the diffusers from coarse to fine bubble did not necessarily result in more efficient aeration. Fine bubble diffusers maintained their ability to transfer oxygen to the biomass as MLSS concentrations increased, but added mixing proved to inhibit oxygen transfer, indicated by the declining blue trendline in Figure 4B. Standard oxygen transfer efficiency (SOTE) normalizes oxygen transfer based on aeration flow rate. Fine bubble diffusers were more 2.5 times more efficient at transferring oxygen based on air flow than coarse, as shown in Figure 4A.

However, the standard aeration efficiency (SAE), which normalizes oxygen transfer based on power consumption, was better for coarse bubble diffusers, shown in Figure 4C. The small pores of the fine bubble diffusers likely create more pressure, which works against the blowers, forcing the blowers to consume more energy to maintain airflow. Selecting blowers designed for fine bubble diffusers may increase the standard aeration efficiency.

Membrane Relaxation Results
More frequent relaxation was induced by lowering the total volume treated per hour, and/or increasing the permeation flow rate. For example, Relaxation #1 treated 300 gallons/hour, or 7.4% less than default conditions (324 gal/hour), but increased relaxation time by 48%. Relaxation #2 and Relaxation #3 treated the same amount of water, but at different flow rates. An increase of 0.5 gpm between #2 and #3 resulted in 125% more relaxation time. Subtle parameter changes led to substantial relaxation time increases.

FUTURE WORK
The relaxation trials indicated that small changes in the system can be significant. The next research step would be drastically changing system parameters and observing trends over longer periods of time.

Another important area to investigate is how aeration could be reduced during relaxation periods. It is possible that the blowers could minimally aerate or completely turn off during the relaxation phase and still prevent membrane fouling. Because aeration is the highest operating cost, reducing total aeration time may reduce operating costs.