Energy Optimization Strategies in a Sequencing Batch Membrane Bioreactor

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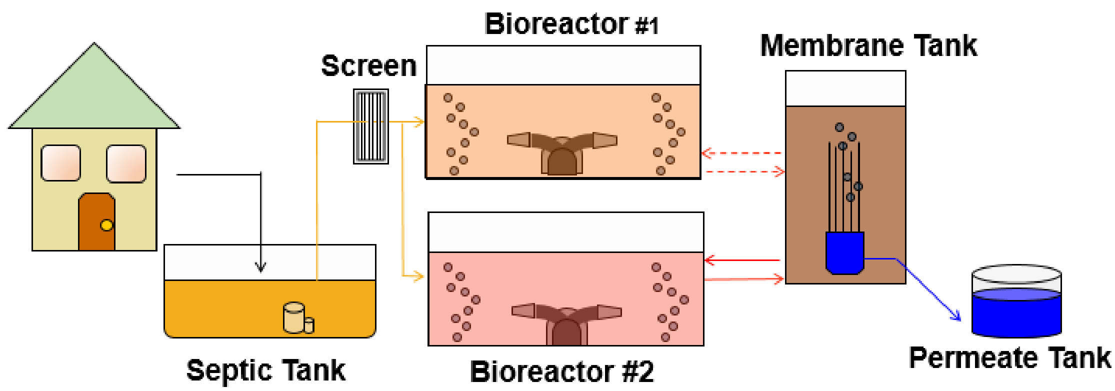
Introduction

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. The following study examines energy optimization strategies to reduce 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.

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).

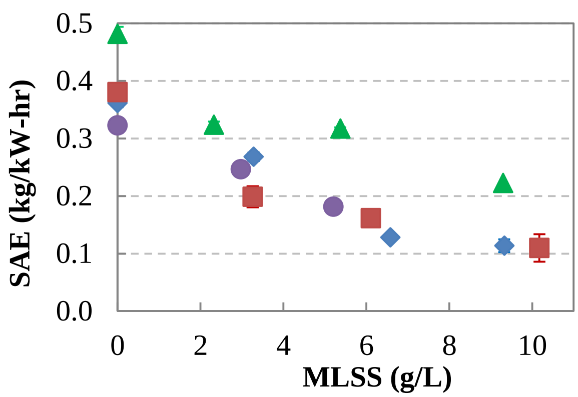


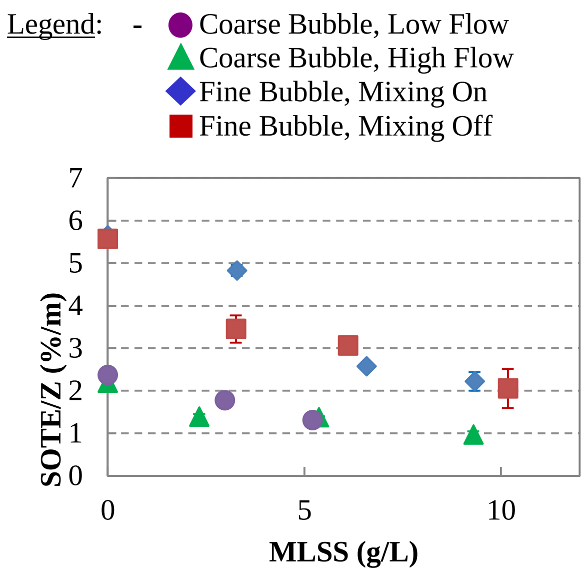
Research Goals

1. First, the mixers and diffusers in bioreactor were upgraded. The mixers were changed from centrifugal pump to vertical shaft, and the diffusers from coarse to fine. The 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 optimizing the aeration system.
2. 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

Oxygen Transfer Results





Upgrading the diffusers from coarse to fine bubble did not necessarily result in more efficient aeration. Shown in the figures, mixed liquor suspended solids (MLSS) is the concentration of suspended solids in the bioreactor. Higher concentrations of MLSS indicate more microbial activity, thus more oxygen uptake.

The standard aeration efficiency (SAE) (graph on the left), which normalizes oxygen transfer based on power consumption, was better for coarse bubble diffusers. Standard oxygen transfer efficiency (SOTE) (graph on the right) normalizes oxygen transfer to 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. This discrepancy between SOTE and SAE suggests that our air blowers need to be upgraded and optimized for fine bubble diffusers.

Membrane Relaxation Results

	Historic Trends	Relaxation #1	Relaxation #2	Relaxation #3
Relaxation/hour	**2.1 min/hour**	**12.1 min/hour**	**5.1 min/hour**	**11.5 min/hour**
Average TMP, ± standard deviation	1.58 psi ± 0.71	1.01 psi ± 0.46	1.07 psi ± 0.41	1.28 psi ± 0.56
Averaged Permeate Flow	4.0 gal/min	3.6 gal/min	3.5 gal/min	4.1 gal/min
Permeation Time/hour	50.6 min/hour	43.2 min/hour	49.8 min/hour	43.7 min/hour
Gallons/hour	324 gal/hour	300 gal/hour	320 gal/hour	320 gal/hour
Flux	19.7 LMH	21.3 LMH	19.8 LMH	22.5 LMH

Average transmembrane pressure (TMP) was lower, from 1.58 psi with 2.1 min/hour of relaxation to 1.07 psi with 5.1 min/hour relaxation treating nearly the same amount of water. However, with Relaxation #3, increasing permeate flow to induce more relaxation did not result in lower average TMP than Relaxation #2, and both conditions treated the same amount of water. There is a point when excessive relaxation forces the permeate pump to work harder and operate at higher TMP to treat the target amount of water.

Conclusions

- Fine Bubble diffusers transfer more oxygen to the SBMBR per volume of air
- Coarse bubble diffusers transfer more oxygen to the SBMBR per kWh consumed.
- Fine bubble diffusers need properly designed blowers to maximize efficiency

- Small changes to the parameters in the SBMBR resulted in major relaxation times fluctuations.
- Too much relaxation can force the system to work harder, and operate at high TMPs to compensate for loss of permeation time.