Get it Twisted: Modeling Helical Flow in a Tubular Membrane for AnMBR

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Introduction

Anaerobic Membrane Bioreactor's (AnMBR's) have the potential to revolutionize municipal wastewater treatment.

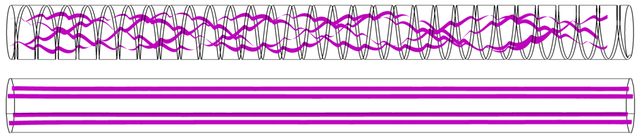
Advantages
- Eliminates aeration costs
- Methane production
- Minimal sludge generation

Disadvantages
- Lack of nutrient recovery/removal
- **Energy loss due to membrane fouling**[1]

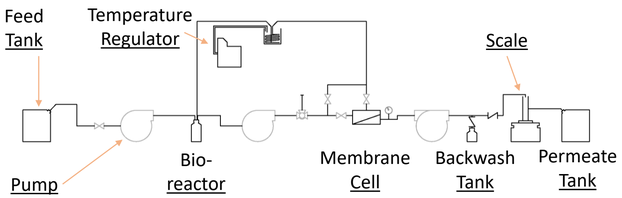
This project focuses on comparing two tubular membranes based on their fouling rates and the power required to operate them.

The Membranes

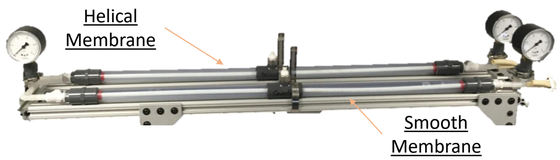
Both membranes are 5mm Pentair tubular UF X-flow membranes. One membrane has a smooth bore, the other has a helical ridge extruded on the inner surface much like a rifle barrel. The **hypothesis** is that the helical membrane will have a lower fouling rate and lower power requirements than the smooth membrane.



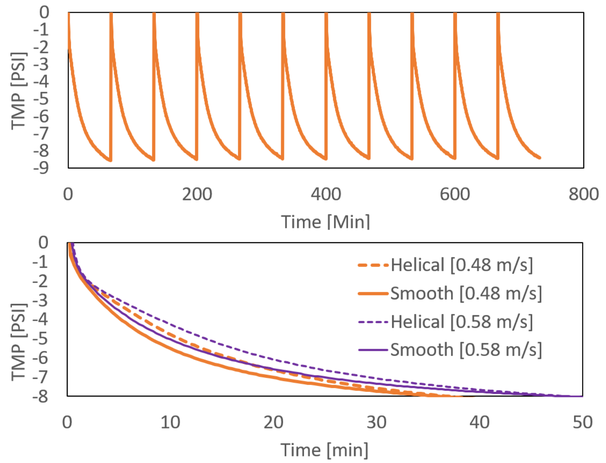
Set Up



The lab-scale AnMBR is set up in a side-stream configuration, with a constant cross-flow across the membrane and backwash triggered by trans-membrane pressure (TMP). The system operates with constant flux.



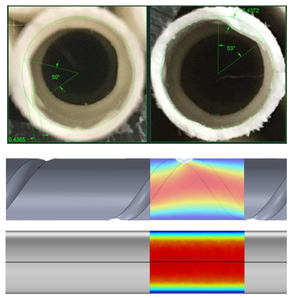
Lab Data

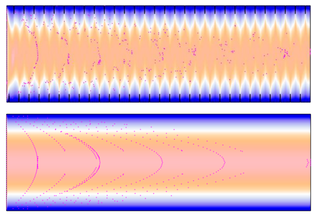


Results from experiments (top) were averaged (bottom) to determine fouling rates at different crossflow velocities. The helical membrane clearly had a lower fouling rate, and both performed better at higher cross-flow.

Modeling

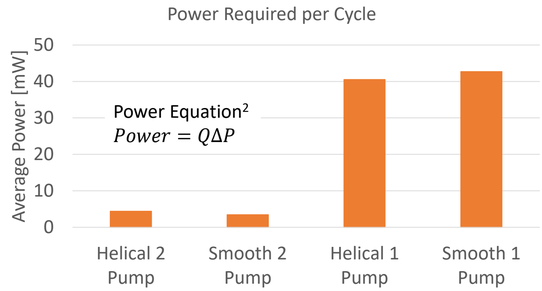
Computational models were created to characterize the crossflow and flux for both membranes. The simulations utilize k-e turbulence models, both 3D and 2D simulations were used. The head loss along the helical membrane is **double** that of the smooth membrane, which agrees with experimental results. According to the model though, the shear delivered to the membrane surface is **not** significantly different between the two membranes.





The velocity profile for the helical membrane is significantly disrupted by the pattern, and it is possible that the additional turbulence contributes to keeping particles in suspension. This behavior could explain the superiority of the helical membrane as seen in the lab results above.

Results



The power requirement for each membrane is dependent on whether it is set up in a one or a two pump system. Our lab system is a two pump system; it has separate recirculation and permeate pumps. Most full-scale systems are one pump systems, with only a feed pump and a valve to provide back-pressure on the membrane. Sample calculations for the helical membrane are provided below

Helical Membrane	Q [L/min]	ΔP [psi]	Power [mW]
Permeate Pump	0.003	5.74	0.18
Recirculation Pump	0.565	0.65	4.22
		Total	4.41
	- or -		
Feed Pump	0.565	6.24	40.55

The helical membrane has a slightly higher power requirement in our lab-scale system, but the calculations indicate it would have a lower power requirement in a full scale system.

Conclusions

- The helical membrane has a lower fouling rate than the smooth membrane
- The helical membrane has higher head loss than the smooth membrane
- Shear delivered to the membrane surface may not be an accurate estimator of fouling rate
- Depending on the system either membrane can be more efficient
- More testing should be done to optimize the operation of the membranes

Acknowledgements

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Cited Works:

1. Smith, Adam L., Lauren B. Stadler, Nancy G. Love, Steven J. Skerlos, and Lutgarde Raskin. 2012. "Perspectives on Anaerobic Membrane Bioreactor Treatment of Domestic Wastewater: A Critical Review." *Bioresource Technology* 122. Elsevier Ltd:149–59
2. Schobeiri, Meinhard T.. Fluid Mechanics for Engineers: A Graduate Textbook. Germany: Springer-Verlag, 2010.

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