Impact of Biological Pretreatment on Reverse Osmosis Performance

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Abstract

Reverse osmosis (RO) is a treatment technology with a high probability of being used to recover potable water from wastewater generated during terrestrial space exploratory missions. Due to the high strength of early planetary base wastewater RO membranes exhibit less than ideal performance in terms of permeate flux and solute rejection. Incorporating biological pretreatment into the process train will improve the RO performance. Lee and Lueptow, 2001 found that RO membranes exhibit poor rejection of urea, a low molecular weight, uncharged compound, and coincidentally a significant component of early planetary base wastewater (EPBW) (Versotko, et al., 2004). Biological pretreatment allows for enhanced ammonification. Additionally, biological oxidation of organic matter decreases the loading of dissolved organic carbon (DOC) on the membrane. A decreased loading of DOC assuages concentration polarization and fouling. The refractory DOC in biological effluent contains soluble microbial products (SMP). Namkung and Rittmann, 1986 found that the majority of SMP in attached biofilm effluent has a molecular weight greater than 10,000 Daltons. The increased molecular weight will enhance rejection of refractory DOC; however, researchers suggest that SMP may play a substantial role in the fouling of membranes (Jarusutthirak and Amy, 2006). The objective of the research is to determine the impact of biological pretreatment on membrane performance. The membrane experiments are performed using a real urine waste stream as well as biological treatment using TTU-WRS, which has been discussed previously (Jackson et al., 2004). A modification of the batch internal recycle membrane test (BalReMT) proposed by DiGiano et al., 2000 is used to evaluate RO membrane performance.

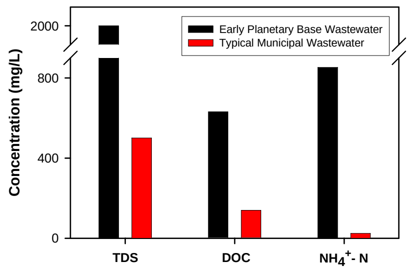
Objective

To determine the impact of biological pretreatment on reverse osmosis performance in terms of flux decline, solute rejection, and fouling layer accumulation.

Background

- Potable water recovery is essential to sustain life on long space flight missions
- Early Planetary Base Wastewater Composition
  - Urine
  - Hygiene Water
  - Humidity Condensate

Wastewater Comparison [2][6]



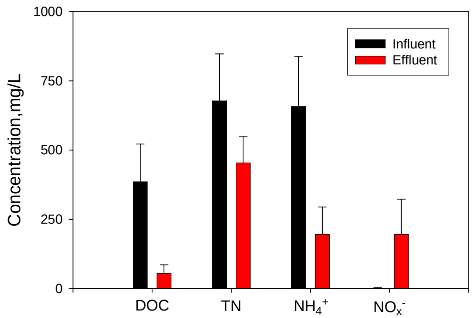
- Anticipated Benefits of Biological Pretreatment
  - Enhanced RO performance
    - Permeate Flux
    - Solute Rejection
      - Enhanced Urea Hydrolysis [1]
      - Increased Molecular Weight
- Anticipated Benefits of Biological Pretreatment Continued
  - Improved Effluent Water Quality
  - Waste Stream Equalization
  - Decreased pH, Less Scaling

Experimental Methods

Texas Tech University – Water Recovery System (TTU-WRS)

- Setup
  - Anoxic Packed Bed
  - Tubular Reactors

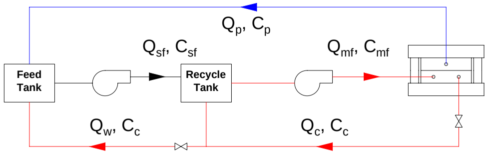
TTU-WRS Water Quality



Batch Internal Recycle Membrane Test (BalReMT) [4]

- Permeate flux and solute rejection are monitored over time
- Simulates recovery and cross-flow velocity
- Permeate and concentrate streams are blended together and returned to the feed tank
- Only 15 Liters needed to perform a test

BalReMT Schematic



- RO Feed Tank Mass Balance
  - Assuming:
    - No Reactions
    - Constant Permeate Flux
    - Constant Solute Rejection

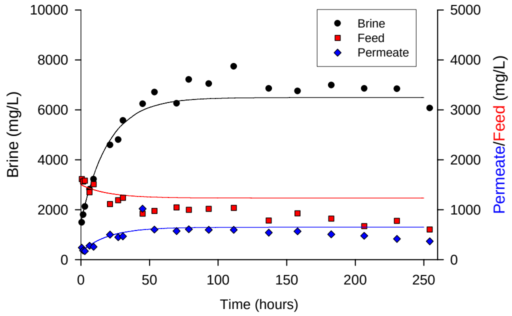
$$Q_w C_c + Q_p C_p - Q_{sf} C_{sf,0} = V \frac{dC_{sf}}{dt}$$

- Operating Conditions
  - Temperature: 45ºC
  - Cross-Flow Velocity: 0.3 m/s
  - Recovery: 90%

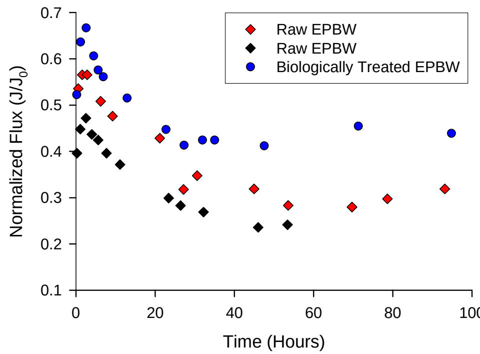
Experimental Results

Validation of Mass Balance

Raw EPBW TDS Concentration

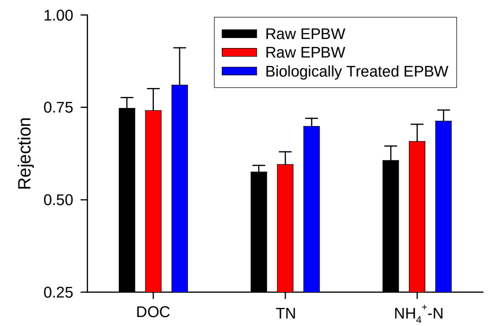


Permeate Flux Comparison

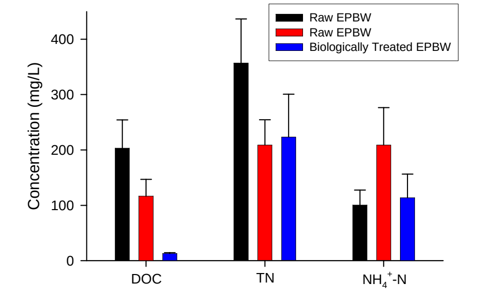


Solute Rejection Comparison

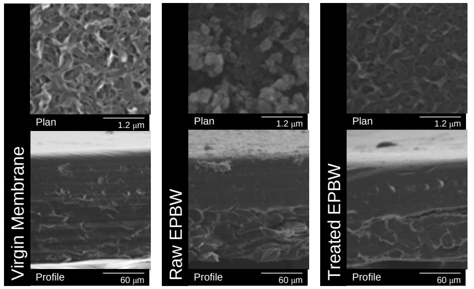
$$R_i = \left(1 - \frac{C_{i,p}}{C_{i,b}}\right)$$



Effluent Water Quality Comparison



SEM Images



Conclusions

- Permeate flux improved by approximately 10%, which decreases the required surface area for the RO unit.
- Improved solute rejection and effluent water quality decreases the loading, and sizing requirements on downstream processes.
- More replicates are needed in order to consider variability in water quality and membrane coupons.

References

[1] Lee, S., and Lueptow, R., "Membrane Rejection of Nitrogen Compounds," *Environmental Science and Technology*, Vol. 35, No. 14, 2001, pp. 3008 – 3018.
[2] Verostko, C. E., Carrier, C., and Finger, B. W., "Ersatz Wastewater Formulations for Testing Water Recovery Systems," *International Conference on Environmental Systems Proceedings*, 2004-01-2448.
[3] Namkung, E., and Rittmann, B. E., "Soluble Microbial Products (SMP) Formation Kinetics by Biofilms," *Water Research*, Vol. 20, No. 6, 1986, pp. 795 – 806.
[4] DiGiano, F. A. et al. "Alternative Tests for Evaluating NF Fouling." AWWA 92(2000): 103-115.
[5] Jarusutthirak, C., Amy, G. "Role of Soluble Microbial Products (SMP) in Membrane Fouling and Flux Decline." *Environmental Science and Technology,* Vol. 40, pp. 969 – 974.
[6] Tchobanoglous, G., Burton, F. L., Stensel, H. D. *Wastewater Engineering: Treatment, Disposal, and Reuse.*, 4th ed., McGraw-Hill, Boston, 2003, Chap. 3.

Acknowledgements

NASA , Johnson Space Center, the Space Science Center at TTU, The Institute for Environmental and Human Health, and the Imaging Center at TTU for funding and support.

Dr. Andrew Jackson, Dr. Audra Morse, Dr. Todd Anderson, and the TTU Water Recovery Team for their constant guidance and patience.