Evaluating the Role of Draw Solute Selection in Forward Osmosis Wastewater Processing

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Abstract:
This research is a component in a larger project aimed at developing a more efficient, effective, and lower cost means of concentrating wastewater for use as a chemical feedstock for microbial fuel cells. Human wastewater streams represent a low-cost and under-utilized source of chemical nutrients, with potential for use as a feedstock for microbial fuel cells. One potential roadblock is the dilute nature of those nutrients as typically found in wastewater effluent. Our project aims to develop a forward osmosis cell and implementation protocol capable of receiving a dilute feed stream of chemical nutrients found in typical wastewater streams and concentrating those nutrients to a level capable of use in a microbial fuel cell. Goals are monetary efficiency, ease of implementation, and efficacy of the derived protocol for operating the cell.

Methods:
A series of 1M reference solutions of MgCl₂·6H₂O, KH₂PO₄, and NH₄HCO₃ were run as draw solutions through the FO cell opposite distilled water feed solution for 6 hours each, with samples of the draw and feed being pulled at 0.2, 4, and 6 hours, respectively. In regard to water recovery, this indicates that MgCl₂ is the optimal choice for operating the cell in a batch process configuration.

Results:
From the testing conducted in these trials, magnesium chloride is the most efficient solute choice for batch FO processing, showing the highest average solvent flux potential. In one of our testing concepts, our derived protocol has show promise in its intended role of enriching wastewater for use in microbial fuel cells, demonstrating strong gains in conductivity, and ion concentration in the processed solution.

Conclusions:

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Linking Research to Education Module
Typically, chemists use spectroscopy and specialized chromatography to establish chemical content and purity. Measuring electrical conductivity of an aqueous solution presents a more generalized approach to generating similar data in terms of solute purity. It also directly addresses the effect of chemical solutes on water’s physical properties.

Throughout our research into the FO cell, electrical conductivity of baseline and treated solutions was used as a general means of establishing cell effectiveness daily in the lab while waiting on samples to be processed at night via ion chromatography. Taking this approach back to my teaching, we will be using EC to establish solution concentrations, and more indirectly, relative purity.

The module outlines lesson that was created using this research experience introduces the concept of aqueous conductivity as a means of verifying solution concentration and purity. Students will synthesize magnesium chloride using a given quantity of magnesium metal precursor, wash and dry the product, and determine experimental yield given the stoichiometry of the base reaction. Students will then prepare a 1 Molar solution with their experimentally derived product and compare its electrical conductivity to a lab standard to assess the purity of their product. Students will then calculate percent error comparing their own solutions EC to that of the standard.

Figure 1: Design for 3d printed forward osmosis cell chamber
Figure 2: Assembled FO cell composed of two chambers separated by CTA membrane
Figure 3: Functional layers of the FO cell
Figure 4: Layout of cell used for all experimental trials
Figure 5: Mass of feed water remaining in reservoir when FO cell was operated with different draw solutes
Figure 6: Mass of feed water remaining in reservoir when FO cell was operated with different draw solutes
Figure 7: A combination of membrane fouling and a reduction in osmotic pressure slowed water flux during FO using wastewater
Figure 8: Increase in water flux over time due to dilution of draw solution

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