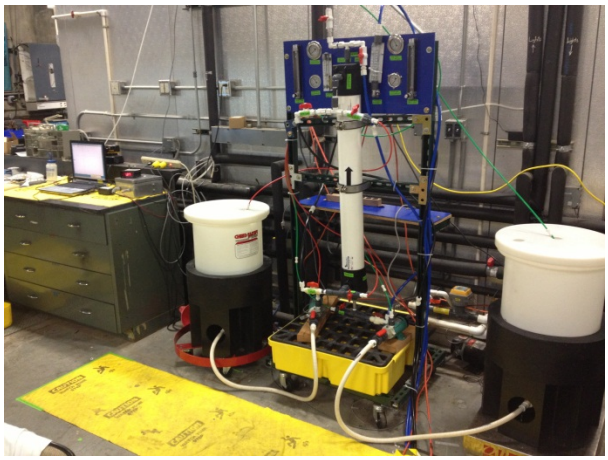
RECLAMATION
Managing Water in the West

Fertilizer Driven Forward Osmosis Water Treatment System Modeling

Research and Development Office
Advanced Water Treatment - Science and Technology Program
Final Report ST-2014-0326-01



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Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Acronyms and Abbreviations

CSM	Colorado School of Mines
FDFO	Fertilizer Driven Forward Osmosis
FO	Forward Osmosis
RO	Reverse Osmosis

Background

The primary content of the final report will be a journal article that includes work by the Colorado School of Mines (CSM) in collaboration with Reclamation, which has not been completed to date. This report will be updated once this article is published. This project was originally funded to include work with NASA-Ames Research Center from bench through pilot scale testing. NASA performed all of the bench scale testing so Reclamation was dependent on their progress. NASA indicated results were not positive, so further work was discontinued. Reclamation has not received the NASA final report or the majority of the NASA results. As part of Reclamation's role in review in FY13 & FY14, a model to examine the Fertilizer Driven Forward Osmosis (FDFO) process was developed. Since Reclamation modeling results and literature review are used in the journal article being prepared, only a summary of Reclamation work is being presented below.

Executive Summary

Forward Osmosis (FO) uses an osmotic pressure gradient across a semi-permeable membrane to produce a flux of water from a lesser osmotic pressure to a fluid with a greater osmotic pressure. The pressure gradient is created by a higher concentration "draw" solution, which has a higher osmotic pressure potential than the feed side (at a lower osmotic pressure). Water permeates the membrane from the feed solution to dilute the draw solution. The higher the osmotic pressure difference across the membrane, the higher the driving force and flux of water for the same membrane. In general, applications that have an impaired water source (such as a wastewater) and a concentrated water source that is to be used as drinking water (such as seawater), forward osmosis has the possibility of a successful application. If the draw solution does not back diffuse through the membrane and is easily recovered or re-concentrated the FO process could also potentially be promising. For many applications, however, this is not feasible, since the desired end product is low salinity fresh water and the feed solution becomes more concentrated. In many of these instances, reverse osmosis (RO) is the appropriate solution where a pressure gradient forces the water through the membrane and leaves the dissolved constituents behind. There is widespread use of RO for desalination of brackish ground water, reused wastewater, and seawater. FO shows some promise in niche applications. One such application of FO investigated as part of this research is fertilizer driven forward osmosis (FDFO).

In FDFO, the draw solution is a dissolved concentrated fertilizer solution. This dissolved fertilizer is used for beneficial use as fertigation water (fertilizer combined with irrigation water). This fertilizer can be dosed into crop irrigation water or used directly in hydroponic applications. The fertigation water requires additional water to dissolve/dilute the fertilizer to the correct concentration needed for a particular crop. This dilution water can come from a fresh water source or a treated impaired water source (e.g. brackish ground water or wastewater) not currently used for other beneficial uses.

In some locations in the U.S., fresh water supplies are very limited and expensive. This is especially the case in areas such as the Navajo Nation in Utah, Arizona, and New Mexico where fresh water is often hauled by truck over significant distances. In addition to the expense, transporting water by vehicle takes time and has a high carbon footprint. Therefore impaired water sources are investigated for possible use. The question asked in this research is "how much water can be extracted from impaired water sources through forward osmosis and used for the production of fertigation water?"

Through a mass balance model with assumed membrane transport properties, Reclamation determined that the amount of water that could be reasonably

extracted from a low salinity impaired water source was low (<20%) compared to the total water needed for fertigation. The remaining fertigation makeup water would have to come from fresh water sources.

Reclamation had some collaboration with project partner NASA-Ames Research Center in answering this question. NASA tested various membranes and draw solutions to answer this question using an experimental testing approach. To date, Reclamation understands that their data has shown similar results to Reclamation's model, that the % of makeup water that can be obtained from the impaired water source is low compared to the water required from fresh water sources. Our model results have also been confirmed by CSM with modeling work they have independently conducted.

It is Reclamation's opinion that FDFO is not an economical solution at this time for all situations that exist in the U.S. The exception, if it were to occur, would be a case where crop production is required, an impaired water source is present to provide makeup water, fresh water costs are extremely high, and it's imperative that maintenance be very low (e.g. low membrane fouling). If it's a case of high water treatment costs with an impaired water source, there are other water treatment technologies that would be more cost effective and are already in widespread use (e.g. water reuse of wastewater using membranes).