NM WRRI Student Water Research Grant Final Report

May 15, 2019

1. **Student Researcher:** Galathara Lekamalage Chathurika Lakshani Bandara
   Faculty Advisors: Dr. Nagamany Nirmalakhandan, Dr. Pei Xu

2. **Project title:** Potable Water Recovery Through Energy Efficient Algal Wastewater Treatment and Hybrid Membrane Processes

3. **Description of research problem and research objectives.**

Increasing demands on energy and freshwater are two major challenges facing the world which upsurge the need of developing energy efficient technologies to treat alternative water sources of impaired quality to recover potable-quality water. Urban wastewater is now being realized as a renewable resource from which water, energy, and nutrients could be recovered for beneficial reuse. Emerging algal-based technologies can potentially replace the current energy intensive wastewater treatment trains due to the advantages of higher energy recovery with minimal energy input, single step treatment, capability of nutrient recovery and removal of heavy metal/toxic organic compounds. But seasonality of the treatment, large footprint, and high energy consumption for harvesting and product recovery have hindered large-scale applications of algal-based wastewater treatment systems.

An integrated algal-based wastewater treatment system coupled with hybrid forward osmosis (FO) and reverse osmosis (RO) has been demonstrated in laboratory studies to be a viable approach to recover potable-quality water from wastewaters. The objective of the proposed study is to demonstrate a pilot scale version of this integrated system at the Las Cruces Wastewater Treatment Plant (LCWTP). Specific goals of this project are to produce potable-quality water and validate the following hypotheses: (i) in addition to removal of bulk organic contaminants and nutrients (N and P) from wastewater, the algal system can contribute to some removal of contaminants of emerging concern (CECs) by adsorption, degradation and/or transformation. (ii) the FO-RO membrane process could be engineered for complete removal of CECs and other contaminants, recovering algal biomass for biofuel production, and producing potable water with zero liquid discharge.

4. **Description of methodology employed.**

Forward osmosis (FO) is a membrane process that has been studied in recent years as new technology for treatment of a wide variety of aqueous solutions. FO utilizes the osmotic pressure differential across a semi-permeable membrane rather than hydraulic pressure differential (as in RO) to extract clean water from impaired water. This result in concentration of a feed stream and dilution of a highly concentrated aqueous solution (referred to as the draw solution) that provides the driving force for separation in the process. The algal photobioreactors have been already established in LCWTP treating primary settled wastewater to discharge quality. The focus of the current study is to investigate a pilot scale FO-RO hybrid process in which FO is being used to extract water from algal treated wastewater using 30 g/L sodium chloride solution (simulating seawater) as a draw solution. By using this hybrid process (Figure 1), salt water can be diluted

before desalination by RO, hence reducing the energy cost of desalination, and simultaneously, contaminants present in the impaired water are prevented from migrating into the product water through two established barriers, the FO membrane and the RO membrane. The recovered algae will be used for biofuel extraction using hydrothermal liquefaction (HTL) which is not part of this study.

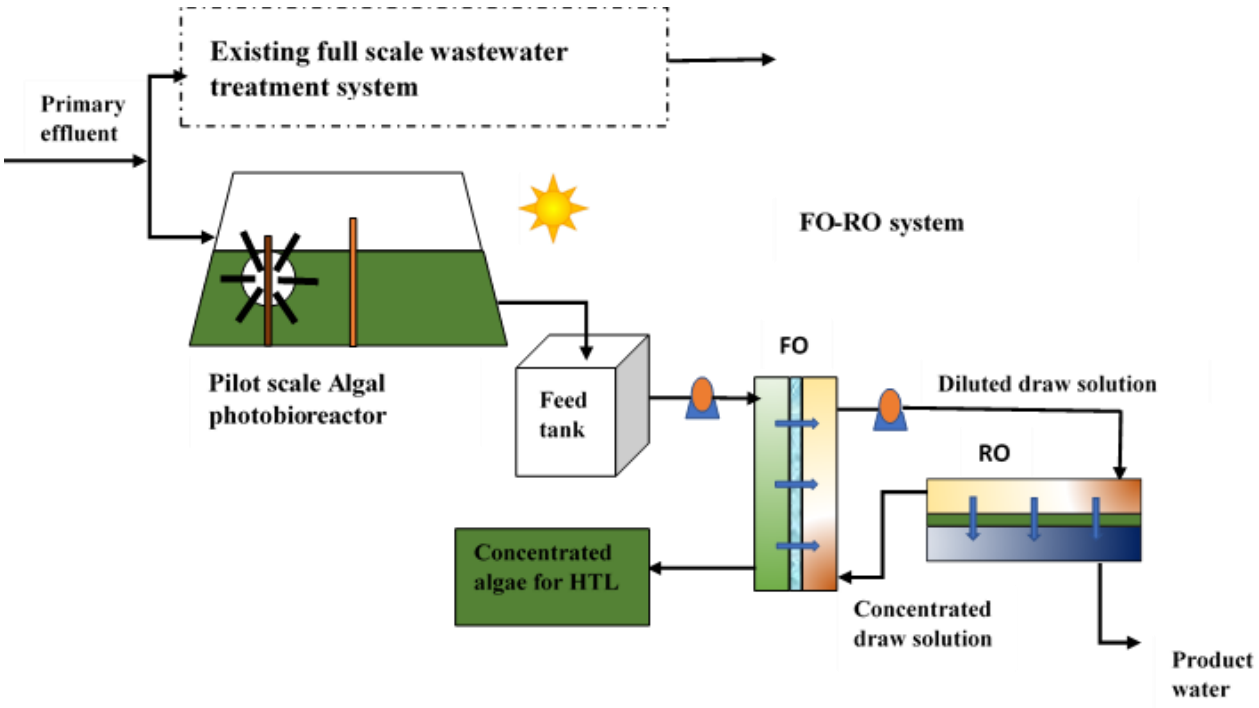

Figure 1:Integrated algal-membrane system

Comprehensive water quality analysis will be conducted throughout the algal and membrane systems using ion chromatograph (IC), inductively coupled plasma mass spectrometry (ICP-MS), UV-VIS absorbance, carbon analyzer, and fluorescence excitation emission matrix (F-EEM). The CECs will be measured by high resolution liquid and gas chromatography/mass spectrometry (LC/MS and GC/MS). The operating conditions of the algal photobioreactors, FO, and RO will be optimized including retention time, water recovery, draw solutions, and membranes. The approaches to prevent membrane fouling and scaling will be investigated.

5. **Description of results; include findings, conclusions, and recommendations for further research.**

As a preliminary study for the pilot-scale FO-RO system, the above mentioned two technologies integrated wherein, the discharge-quality effluent produced by the algal system was purified further by the bench-scale FO-RO membrane system (at NMSU) to produce potable-quality water. Detailed chemical analysis of the product water from the bench-scale FO-RO system confirmed that it met the primary and secondary drinking water standards. Based on the bench-scale data, the hybrid FO-RO membrane system can be upgraded to pilot-scale (at LCWTP) for

simultaneous wastewater treatment and potable water recovery in a sustainable and economical manner to fulfill water needs in arid/semi-arid regions.

Pilot-scale FO-RO membrane system construction has been in progress at LCWTP and, pilot scale studies will be started to fulfill the objectives of this project. Pilot-scale study outcomes can be used to develop innovative approaches, which will result in complete reuse and recycling of wastewater achieving zero liquid discharge to close the local water cycle.

6. **Provide a paragraph on who will benefit from your research results. Include any water agency that could use your results.**

In addition to removal of bulk organic contaminants and nutrients (Nitrogen and Phosphorous) from wastewater, the algal system can contribute to some removal of contaminants of emerging concern (CECs) by adsorption, degradation and/or transformation. This improves the treated water quality in comparison with conventional treatment processes. The FO-RO membrane process could be engineered for complete removal of CECs and other contaminants, recovering algal biomass for biofuel production, and producing potable water with zero liquid discharge, which minimize the health impacts related with treated wastewater discharge to natural water bodies. Water reuse reduce energy consumption of both wastewater treatment and water treatment by minimizing water discharge and water pumping related energy consumption respectively. Hybrid FO-RO process can produce drinking water, which meets primary and secondary drinking water standards, because water passes through two dense membranes which can reject almost all the contaminants in water. In long term, New Mexico citizens can have access to high quality drinking water at a lower cost while protecting environment in a sustainable manner.

Water and wastewater utilities can use the data for their future implementations.

7. Describe how you have spent your grant funds. Also provide your budget balance and how you will use any remaining funds. If you anticipate any funds remaining after May 15, 2019, please contact Carolina Mijares immediately. (575-646-7991; mijares@nmsu.edu)

8. List presentations you have made related to the project.

9. List publications or reports, if any, that you are preparing. Remember to acknowledge the NM WRRI funding in any presentation or report that you prepare.

10. List any other students or faculty members who have assisted you with your project.

Dr. L. Lin : Postdoctoral researcher
Dr. W. Jiang: Postdoctoral researcher
I.S.A. Abeysiriwardhana-Arachchige : Graduate student

11. Provide special recognition awards or notable achievements as a result of the research including any publicity such as newspaper articles, or similar.

12**. Provide information on degree completion and future career plans. Funding for student grants comes from the New Mexico Legislature and legislators are interested in whether recipients of these grants go on to complete academic degrees and work in a water-related field in New Mexico or elsewhere.**

I am planning to complete the qualifying exam in Fall 2018 and continue my studies for the Ph.D. I like to continue my career as a researcher in the field of water and environmental engineering to contribute to the well-being of humans and preservation of the ecosystem in arid regions, such as New Mexico, with limited freshwater resources.
.