Life Cycle and Techno-Economic Assessment for a Coupled Algal-Membrane System Versus Conventional Wastewater Treatment and Potable Reuse Process

A. Lugo[1], G.L.C.L. Bandara, I.S.A. Abeysiriwardana-Arachchige, N. Nirmalakhandan, X. Xu, J. Penteado, P. Xu[2]
Department of Civil Engineering, New Mexico State University, Las Cruces, NM
[1]alugo12@nmsu.edu | [2]pxu@nmsu.edu

The current wastewater treatment infrastructure is often deemed unsustainable and resource-inefficient due to its negative environmental impacts, high energy demand, and high economic investment. The conversion of wastewater treatment to water and resource recovery centers offers a promising pathway for sustainable sewage treatment and resource conservation, which will lead to ecological benefits, augmentation of local water supplies, enhanced environmental sustainability, and a better economic investment. This study involves the application of a life cycle and a techno-economic assessment methodology for two theoretical potable reuse systems to determine both the environmental footprint in terms of greenhouse gases and energy, as well as the possible economic impact of its implementation.

The *main system* consists of (i) an innovative algal-based wastewater treatment coupled with dual forward osmosis and seawater reverse osmosis for high-quality water production, and hydrothermal liquefaction to produce bioenergy from the harvested algal biomass; while the *benchmark system* referenced consisted of (ii) secondary biological treatment, microfiltration, brackish water reverse osmosis, ultraviolet/advanced oxidation process with granular activated carbon, and anaerobic digestion for waste management. The overall water recovery considered, based on the recovery efficiency of the membrane processes employed, were 88% and 76% for the main and benchmark system, respectively.

The energy, greenhouse gas emissions, and water production costs were normalized and compared considering 1 m^3 of water recovered as a functional unit. The main system was estimated to consume around 4.59 kWh/m^3 of energy and emit 1.37 kg of CO_2 eq/m^3, with energy and emissions coming mostly from the high energy demand of the seawater reverse osmosis. For the benchmark system, the energy consumption totaled 4.75 kWh/m^3, and the system was estimated to generate emissions of 2.34 kg of CO_2 eq/m^3. The total water production cost favors that of the main system, with a cost of $\$2.06/m^3$, compared to that of the benchmark system which is $\$2.19/m^3$.

The results obtained in this study prove that the main system has a higher environmental resilience with the recovery of bioenergy and nutrients from wastewater achieving zero waste disposal, a higher overall water recovery, and a lower investment cost overall compared to a traditional potable reuse benchmark system. With the application of energy recovery devices and further optimization of the forward osmosis membrane in the future, the main system shows further improvement both environmentally and energy-wise. With adequate design and implementation, this system provides a paradigm shift in wastewater treatment and recovery in the future.