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Comparative Demonstration of Gas-Sparged and GAC-Fluidized Anaerobic Membrane Bioreactors for Sustainable Wastewater Treatment and Resource Recovery

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Background/Objectives. Wastewater/water treatment and distribution currently consumes about 4% of the total U.S. energy demand, and wastewater secondary treatment comprises about half of this demand. The majority of wastewater treatment energy demand is associated with aeration and sludge dewatering. Whereas conventional aerobic treatment systems rely on compressing and conveying large quantities of air or oxygen to facilitate cell respiration and oxidation of organics in the wastewater, anaerobic processes do not require this energy intensive process. In addition to eliminating aeration, anaerobic processes decrease the volume of sludge produced. Anaerobic biological processes have been recognized as the most suitable pathway towards energy neutrality in wastewater treatment. The objective of this ESTCP demonstration is to determine the cost and performance of two anaerobic membrane bioreactor (AnMBR) for sustainable wastewater treatment.

Approach/Activities. AnMBR technology is the marriage of anaerobic biological treatment and physical membrane separation. The main elements of the AnMBR system are the anaerobic bioreactor and membrane tank where ultrafiltration (UF) membranes are located and solid/liquid separation occurs. The anaerobic process involves multiple steps of disintegration, hydrolysis, fermentation, and methanogenesis resulting in conversion of BOD and organic carbon to energy-rich biogas containing methane and carbon dioxide. The physical separation process is UF that serves to: 1) maintain a high suspended solids concentration in the bioreactor tank and 2) produce a solids-free permeate. Hollow fiber UF membranes exclude solid particles larger than 0.04 microns resulting in a high permeate quality. Two methods of membrane cleaning are being evaluated – biogas-sparged AnMBR (Ft. Riley in Kansas) and GAC-fluidized AnMBR (Bucheon wastewater treatment plant in South Korea).

Results/Lessons Learned. Both AnMBR systems are reducing BOD_5 to less than 20 mg/L with a suspended solids-free permeate. Net membrane flux of 9 L m^{-2} d^{-1} while maintaining transmembrane pressure less than 0.3 bar is so far being observed with both systems. The Bucheon plant currently has an operating energy consumption of 0.13 kWh/m^3 with a hydraulic residence time of 3.2 h. Gaseous methane production is being observed however the majority of the methane in both systems remains dissolved in the permeate. The systems are net energy-negative (i.e., more energy is consumed than produced) unless dissolved methane recovery is conducted. The Ft. Rilely system will evaluate use of a hollow-fiber gas-liquid contactor and a vacuum pump to recover dissolved methane. Calculations suggest the system will be energy neutral or positive if dissolved methane is recovered. Solids production is < 0.2 g TSS/g COD. Continuing operation will evaluate: 1) performance as wastewater temperature decreases in the winter, 2) optimization to achieve energy neutrality, 3) microbial community characteristics and changes, and 4) downstream treatment of the permeate to recover nutrients and produce a potentially reusable water.