Development of Membrane Based Operations for Emerging Separations Challenges

Ranil Wickramasinghe
Ralph Martin Department of Chemical Engineering
University of Arkansas

Abstract

Membrane based separations are attractive for a number of reasons such as easy scale up, lower operating cost and the potential for significant process intensification. For applications in bioseparations linear scale up is important given the regulatory approvals needed for a manufacturing process. For water treatment applications such as reverse osmosis, lower operating costs compared to evaporative processes are a major advantage. Catalytic membranes provide the possibility of combining reaction and separation into one unit operation which leads to significant process intensification. This could enable the economic conversion of waste biomass to bio-based chemical intermediates. In this presentation the potential for membranes in each of these areas will be discussed.

Biopharmaceutical manufacturing processes make use of cell lines to produce therapeutics such as monoclonal antibodies, fusion proteins etc. Today, biopharmaceutical manufacturing processes are typically run in batch mode. There is however a great deal of interest in developing continuous biomanufacturing processes in order to minimize batch to batch variation. Membrane based bioseparations are run in batch mode. Development of continuous membrane based bioseparations is essential. Here virus filtration will be highlighted. Virus filtration is routinely used for validation of virus clearance in the manufacture of biopharmaceutical products. Validation of virus clearance is required by regulatory agencies. Development of virus filtration operations that are compatible with continuous biomanufacturing operations will be essential. Our results indicate that development of membranes that are compatible with constant flux operation as opposed current practice which is based on constant pressure operation will be required.

Sustainable waste management practices will be essential in order promote a circular economy. The use of electrocoagulation as a feed pretreatment operation prior to membrane distillation will be described. Today highly impaired hydraulic fracturing flow back water is typically reinjected into a geologically isolated formation in the Earth's crust. However, treating this highly impaired water for beneficial uses will promote a circular economy. The advantages of an integrated electrocoagulation, microfiltration and membrane distillation process for maximizing water recovery from hydraulic fracturing produced water will be described.

The overall agricultural industry contributes more than 25% to world greenhouse gas emissions. Agricultural residues represent an abundant source of fuels and chemical intermediates. Here lignocellulosic biomass hydrolysis and dehydration has been conducted using a synthetic polymeric solid acid catalyst consisting of dual polymer chains grafted from the surface of a ceramic membrane. These novel, patented, polymeric solid acid catalysts are superior to cellulases enzymes as they can be operated at a higher temperature and at a much higher hydrolysis rates. These catalysts are stable and maintain high catalytic activity over repeated runs. Moreover, they can be easily regenerated and are environmentally friendly. These polymeric solid acid catalysts can be used not only for hydrolysis but also dehydration of cellulose leading to the production of 5-hydroxymethylfurfural (HMF) or levulinic acid. By using a catalytic membrane, reaction and separation can be combined into a single unit operation leading to an intensified process.