Chemical Engineering Doctoral Defense

Development of pervaporation membranes and integration into system design for space flight wastewater management

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Abstract

Pervaporation is a membrane process suited to complex and highly contaminated wastewaters. Pervaporation desalination is an emerging area of study where the development of high-performance membranes is necessary to propel the field forward. Our research demonstrated that sulfonated block polymer membranes (Nexar™)show excellent permeance (water passage normalized by driving force) of as much as 135.5 ± 29 kg m-2 hr-1 bar-1, with salt removal values consistently equal to or greater than 99.5%. Another challenging water management scenario is in spaceflight situations, such as on the International Space Station (ISS). Spaceflight wastewaters are highly complex, with low pH values, and high levels of contaminants. Current processes produce 70% wastewater recovery, necessitating the handling and processing of concentrated brines. Since recoveries of 85% are desired moving forward, further efforts in water recovery are desirable. An area of concern in these ISS water treatment systems is scalant deposition, especially of divalent ions such as calcium species. Zwitterions are molecules with localized positive and negative charges, but an overall neutral charge. Zwitterions have been used to modify the surface of membranes have shown to decrease fouling. By building a copolymer between zwitterions and other polymers, we created a zwitterion layer on top of previously studied Nexar™ membranes. This coating demonstrates great promise to combat scaling, as it increases the hydrophilicity of the membrane surface measured via contact angle. The zwitterion membranes experienced reduced scaling, with the greatest difference being between 1617 ± 241 wt% on control membranes, to 317 ± 87 wt% on zwitterion coated membranes in the presence of CaCl2. In treating spaceflight wastewater, these zwitterion membranes are effective at retaining the acid in the feed, going from a pH value of 2 to 7 and reducing the contamination level of the feed, with a removal value of 99.3 ± 0.4%, measured through conductivity. These membranes also perform well in separation processes that do not require extreme vacuum and can be operated passively. By optimizing both membrane material properties and process conditions, achieving increased high levels of water recovery from spaceflight wastewaters is attainable.

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