

Selective Lithium Recovery From Complex Brines Using Crown-Functionalized LDH–PEI Hybrid Membranes

Almogren, Fatema (School: Rowad Alkhaleej International School)

Global lithium demand is projected to increase by nearly 4000% by 2040 due to expansion of electric vehicles and energy storage systems; however, current extraction methods are water-intensive and lack selectivity in complex multi-ion brines. This study developed a dual-mechanism membrane integrating molecular recognition and electrostatic exclusion for selective lithium recovery. The membrane consisted of layered double hydroxide (LDH), hydroxymethyl-12-crown-4 for lithium-specific binding, and post-quaternized polyethyleneimine (PQ-PEI). Membranes containing 2, 5, and 10 wt% PEI were fabricated, along with control membranes without crown ether functionalization. Membrane performance was evaluated using synthetic brines under 1 bar dead-end filtration and validated using real desalination brine under cross-flow conditions. Screening and real brine experiments, including controls, were conducted in duplicate. The optimized 5 wt% PEI membrane achieved 98% lithium passage with high rejection of competing ions (Na^+ 98%, Mg^{2+} 90%, Ca^{2+} 98%, K^+ 99%), resulting in Li/Na and Li/Mg selectivity values of 49 and 9.8. The membrane exhibited high initial flux (~190 LMH) with stable performance. Control membranes showed reduced lithium selectivity. Scale-up testing was performed in triplicate and demonstrated consistent selectivity and stable flux, indicating good scalability. This system demonstrates high-selectivity lithium recovery with strong potential for scalable extraction from realistic brine conditions.

Awards Won:

Fourth Award of \$600

King Abdulaziz &

his Companions Foundation for Giftedness and Creativity: NOT TO BE READ -- \$200 cash prize for each Enrichment award recipient

King Abdulaziz &

his Companions Foundation for Giftedness and Creativity: Mawhiba Universal Enrichment Program awards (and a \$200 cash prize)