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Electrodialysis membrane desalination with diagonal membrane spacers: a review

Sajjad Khudhur Abbas Al-Amshawee[1] · **Mohd Yusri Bin Mohd Yunus**[1,2]

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Abstract

Electrodialysis desalination uses ion exchange membranes, membrane spacers, and conductors to remove salt from water. Membrane spacers, made of polymeric strands, reduce concentration polarization. These spacers have properties such as porosity and filament shape that affect their performance. One important property is the spacer-bulk attack angle. This study systematically reviews the characteristics of a 45° attack angle of spacers and its effects on concentration polarization and fluid dynamics. Membrane spacers in a channel create distinct flow fields and concentration profiles. When set at a 45° attack angle, spacers provide greater turbulence and mass-heat transfer than traditional spacers. This is because both the transverse and longitudinal filaments become diagonal in relation to the bulk flow direction. A lower attack angle (<45°) results in a lower pressure drop coupled with a decline in wakes and stream disruption because when the filaments are more parallel to the primary fluid direction, the poorer their affect. This research concludes that membrane spacers with a 45° spacer-bulk attack angle function optimally compared to other angles.

Keywords Ion exchange membrane electrodialysis · Concentration polarization · Pressure drop · Mass transfer · Boundary layer · Hydrodynamics in membrane desalination · Hydraulic retention time · Membrane spacers · Bulk-spacer attack angle

Introduction

For more than 50 years, electrodialysis has been used conventionally to produce potable water from brackish water sources on a large industrial scale (Al-Amshawee et al. 2020a). Electrodialysis, as a cost-effective process, has been widely used in purification of biological solutions (Sato et al. 1995), table salt production (Strathmann 2010), demineralization of mixed solution (Thampy et al. 1999), heavy metals removal (Fu and Wang 2011), chemical processes (Fidaleo and Moresi 2006), drug and food industries, and saline water treatment (Jiang et al. 2014). For instance, Ibáñez et al. (2013) converted reverse osmosis (RO) concentrate into acid and base products using bipolar membrane electrodialysis.

One of the main challenges in the desalination and electrochemical processes is the occurrence of polarization. According to Schwinge et al. (2004) and Jalili et al. (2018), polarization is an inherent system flaw caused by the quick convective transport of solutes to the membrane surface in contrast to the slow back-diffusion to the feed stream. Tadimeti et al. (2016) defined that concentration polarization at the solution-membrane interface is caused by variations in ion transport between the solution phase and the membrane phase, which imparts resistance to the whole stack's mass transfer. Figure 1 depicts the boundary layers of a spacer-less channel.

The high concentration in Fig. 1 (a) in the concentrate compartment adjacent to the membrane's surface might be caused by a fouling layer or solid deposits. If mixing activities are insufficient and mass transfer is hampered by concentration polarization at the membrane's surface, the concentrate compartment will be impacted in the same way as the dilute compartment. The effects of concentration polarization could even be somewhat less prominent in the

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✉ Sajjad Khudhur Abbas Al-Amshawee
sajjadkhudhur@ump.edu.my

[1] Centre for Sustainability of Ecosystem and Earth Resources (Earth Centre), Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia

[2] Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia