Environmental Research 219 (2023) 115115

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Electrodialysis desalination: The impact of solution flowrate (or Reynolds number) on fluid dynamics throughout membrane spacers

Sajjad Khudhur Abbas Al-Amshawee [a,*], Mohd Yusri Bin Mohd Yunus [a,b]

[a] *Centre for Sustainability of Ecosystem & Earth Resources (Earth Centre), Universiti Malaysia Pahang, 26300, Pahang, Malaysia*
[b] *Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang, 26300, Pahang, Malaysia*

ARTICLE INFO

Keywords:
Solution flowrate
Electrodialysis desalination technology
Membrane spacer
Mass transfer
Fluid dynamics
Wastewater treatment

ABSTRACT

The incorporation of a spacer among membranes has a major influence on fluid dynamics and performance metrics. Spacers create feed channels and operate as turbulence promoters to increase mixing and reduce concentration/temperature polarization effects. However, spacer geometry remains unoptimized, and studies continue to investigate a wide range of commercial and custom-made spacer designs. The in-depth discussion of the present systematic review seeks to discover the influence of Reynolds number or solution flowrate on flow hydrodynamics throughout a spacer-filled channel. A fast-flowing solution sweeping one membrane's surface first, then the neighboring membrane's surface produces good mixing action, which does not happen commonly at laminar solution flowrates. A sufficient flowrate can suppress the polarization layer, which may normally require the utilization of a simple feed channel rather than complex spacer configurations. When a recirculation eddy occurs, it disrupts the continuous flow and effectively curves the linear fluid courses. The higher the flowrate, the better the membrane performance, the higher the critical flux (or recovery rate), and the lower the inherent limitations of spacer design, spacer shadow effect, poor channel hydrodynamics, and high concentration polarization. In fact, critical flow achieves an acceptable balance between improving flow dynamics and reducing the related trade-offs, such as pressure losses and the occurrence of concentration polarization throughout the cell. If the necessary technical flowrate is not used, the real concentration potential for transport is relatively limited at low velocities than would be predicted based on bulk concentrations. Electrodialysis stack therefore may suffer from the dissociation of water molecules. Next studies should consider that applying a higher flowrate results in greater process efficiency, increased mass transfer potential at the membrane interface, and reduced stack thermal and electrical resistance, where pressure drop should always be indicated as a consequence of the spacer and circumstances used, rather than a problem.

1. Introduction

In 1890, Maigrot and Sabates initially introduced the theory of electrodialysis desalination, and its industrialization began more than 50 years ago. The governance of electrodialysis is directed by the development of ion exchange membranes (IEMs), which results in high extraction of solutes without the need for phase change, reaction, or chemicals. For over 60 years, electrodialysis has been used in the treatment of brackish water, industrial wastewater, municipal wastewater as well as in the drug and food industries, table salt production (Strathmann, 2010), chemical processes (Fidaleo and Moresi, 2006), biotechnology, electronics, heavy metals removal (Al-Amshawee et al., 2020a), and acid and base production due to its ability to remove ionic and non-ionic elements under the influence of an electric current. Electro driven membrane processes using ion-exchange membranes are not only a concept of applied electrochemistry, but also of separation techniques, such as electrodeionization. A summary of the main advantages and disadvantages of various separation methods is listed in Table 1 in comparison to the electrodialysis process.

Despite considerable breakthroughs in membrane processes and being widely recommended and researched in a broad range of uses, the membrane separation industry continues to suffer concentration polarization challenges, particularly in the electrodialysis operation. The effects of concentration polarization are taken into account in most separation processes by correlating the concentration gradient of components at the feed-membrane to the bulk of the feed mixture; the

---

* Corresponding author.
E-mail addresses: sajjadkhudhur@ump.edu.my, sajjad.hillawi@hotmail.com (S.K.A. Al-Amshawee).

https://doi.org/10.1016/j.envres.2022.115115
Received 9 May 2022; Received in revised form 13 November 2022; Accepted 17 December 2022