Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2021.26703

214 (2021) 312–320
February

Mathematical modeling of scaling-free membrane module by combining residence time distribution, metastability, and induction time

Marian Turek[a], Krzysztof Piotrowski[b,*], Piotr Dydo[a], Krzysztof Mitko[a], Ewa Bernacka[c], Agata Jakóbik-Kolon[a]

[a]*Faculty of Chemistry, Department of Inorganic, Analytical Chemistry and Electrochemistry, Silesian University of Technology, B. Krzywoustego 6, 44-100 Gliwice, Poland, Tel./Fax: (+4832) 2371383, 2372277; email: marian.turek@polsl.pl (M. Turek)*
[b]*Faculty of Chemistry, Department of Chemical Engineering and Process Design, Silesian University of Technology, M. Strzody 7, 44–101 Gliwice, Poland, Tel./Fax: (+4832) 2371461; email: krzysztof.piotrowski@polsl.pl*
[c]*PolymemTech Sp. z o.o., ul. Wołodyjowskiego 46, 02-724 Warsaw, Poland, email: laskowska.ewi@gmail.com*

Received 5 May 2020; Accepted 23 July 2020

ABSTRACT

In highly concentrated solutions, with complex ionic composition, the nuclei formation and their surface deposition/growth might result in a severe membrane scaling risk and limit their efficiency. Some scaling prevention techniques exist which are based on correction in feedwater composition and/or antiscalant addition, affecting either ionic equilibriums or sparingly soluble salts formation (nucleation, crystal growth, and deposition). Contrary, a different approach seems to be rational. It includes specific physical aspects of the scaling-underlying phenomena. The idea is based on the identification of the scaling-free operating conditions by adjusting the time required for the ions to pass through RO module with nucleation induction times (metastability) of the potential scalants. Stable performance of the membrane module may be possible without any antiscalants addition. Analysis of membrane modules, of different residence time distributions (effect of spacers geometry and flow rate), was done. The authors' own experimental data concerning the maximal attainable supersaturation C_{max} of $CaSO_4$ for different dC/dt and NaCl concentrations (C_{NaCl}), were coupled with literature data of induction time t_{ind} in these systems. As a result simulation of membrane safe work scenarios with the identification of the operational limits was possible. Some economically optimal exploitation strategies and practical design rules were suggested.

Keywords: Scaling; Residence time distribution; Metastable zone; Induction time; Nucleation

* Corresponding author.