

Nanofiltration membranes and processes: A review of research trends over the past decade



Darren L. Oatley-Radcliffe^{a,b,*}, Matthew Walters^{a,b}, Thomas J. Ainscough^{a,b}, Paul M. Williams^a, Abdul Wahab Mohammad^c, Nidal Hilal^a

^a Centre for Water Advanced Technologies and Environmental Research (CWATER), College of Engineering, Swansea University, Fabian Way, Swansea SA1 8EN, UK

^b Energy Safety Research Institute, College of Engineering, Swansea University, Bay Campus, Swansea, SA1 8EN, Wales, UK

^c Centre for Sustainable Process Technology (CESPRO), Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor Darul Ehsan, Malaysia

ARTICLE INFO

Keywords:

Nanofiltration
Review
Research trends
Membranes
Statistics

ABSTRACT

Nanofiltration technology has come a long way since first inception in the late 1980s. Research activity in this area covers a great many topics and the aim of this review is to quantify the level interest in each of these areas. The number of annual publications directly related to nanofiltration technology has been harvested from ScienceDirect since 2007. This quantification of research has shown that interest in nanofiltration technology has grown over the past decade, particularly over the past five years. The primary journals reporting articles on nanofiltration are the Journal of Membrane Science, Desalination and Separation and Purification Technology, although articles have been spread across a further 139 journals. Unsurprisingly, the major topics of interest have been water processing, membrane fabrication and membrane surface modification. There has been clear growth in the areas of organic solvent nanofiltration, pharmaceutical and biological applications, design and economics of nanofiltration processes and review articles. Nanofiltration modelling has received less support over the period reviewed and has experienced a steady decline.

Clearly the overall growing trend in nanofiltration research indicates that the technology remains popular and this interest should materialise into further applications for a robust and sustainable future.

1. Introduction

Nanofiltration membranes have come a long way since inception in the late 1980s. With properties between those of ultrafiltration (UF) and reverse osmosis (RO) membranes, nanofiltration membranes continue to see increasing interest due to their versatility as a separation tool. Their pore size is typically of the order of 1 nm, which corresponds to a molecular weight cut-off (MWCO) in the range of 100–5000 Da. Nanofiltration membranes also exhibit a moderate level of charge due to the dissociation of surface functional groups or the adsorption of charged solutes. For example, polymeric NF membranes contain ionisable groups such as carboxylic and sulfonic acid groups which result in charged surfaces in the presence of an aqueous feed solution. Nanofiltration membranes operate with no phase change and typically have high rejections of multivalent inorganic salts and small organic molecules at modest applied pressures. This makes the separation process highly competitive in terms of selectivity and cost benefit when compared to traditional separations. Thus, NF has found wide

application across a range of industrial sectors including water and wastewater treatment, pharmaceutical and biotechnological processes, and food engineering to name a few. Various aspects of NF membranes have been explored in a number of recent review papers [1–3], these include treatment, pre-treatment, modelling, atomic force microscopy, and some of the pitfalls of NF technology. In addition, a comprehensive account of NF membranes has been provided in several reference books [4,35–37]. The aim of this review is to collate and highlight the trends in research progress related to nanofiltration membranes and processes over the past decade, from 2007 onwards. To this end, the ScienceDirect platform has been used to collate academic papers across the spectrum of journals available. The subsequent processing of articles has removed any papers that claim keywords or text such as ‘nanofiltration’ but does not actually include work in the respective field. For example; the term nanofiltration may appear quite legitimately in the text of a paper; but on closer inspection the paper actually deals specifically with ultrafiltration. Where this is the case; these papers have not been included in this review with the goal to only include relevant

* Corresponding author at: Centre for Water Advanced Technologies and Environmental Research (CWATER), College of Engineering, Swansea University, Fabian Way, Swansea SA1 8EN, UK.

E-mail address: d.l.oatley@swansea.ac.uk (D.L. Oatley-Radcliffe).

<http://dx.doi.org/10.1016/j.jwpe.2017.07.026>

Received 27 April 2017; Received in revised form 20 July 2017; Accepted 27 July 2017
2214-7144/ © 2017 Elsevier Ltd. All rights reserved.

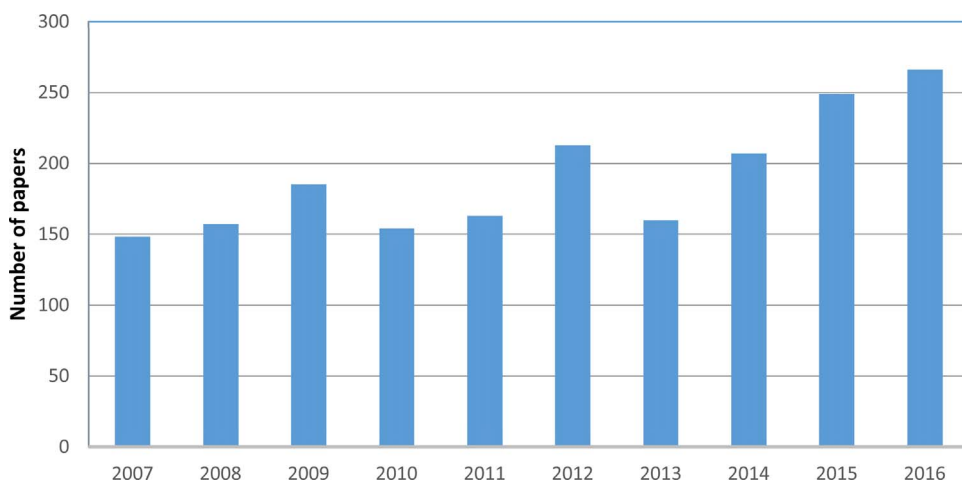


Fig. 1. Number of nanofiltration research articles published since 2007 according to ScienceDirect.

research specific to nanofiltration.

2. General research trends since 2007

The trend in nanofiltration research has been generally increasing since 2007 and is illustrated in Fig. 1. At the time of writing, there have been 1902 journal articles published on Science Direct related to the topic of nanofiltration. Due to the versatility of nanofiltration membranes, these articles cover a range of topics, for example membrane fabrication, membrane modification, desalination, and Organic Solvent Nanofiltration (OSN – formerly known as Solvent Resistant Nanofiltration [SRNF]) all showing that nanofiltration is an innovative technology that has a wide range of applications.

In total there have been publications across some 142 journals spanning the topic of nanofiltration. In 2007 there were 148 articles published related to nanofiltration membranes and processes. This number, barring small spikes in 2009 and 2012, was almost constant until 2013; beyond which there has been a significant year on year increase to 266 papers in 2016. The spike in 2012 is most likely attributable to publications arising from the Euromembrane Conference of that year. Fig. 2 indicates the major journals that have published articles related to nanofiltration. The data clearly shows that main journals publishing nanofiltration papers are The Journal of Membrane Science (27.39%), Desalination (22.97%), Separation and Purification Technology (10.78%). Collectively these three journals account for more than 60% of all nanofiltration publications with the remainder of articles spread across a further 139 different Journals.

A breakdown of the publication topics from the total amount of publications from 2007 to present is provided in Fig. 3. The majority of the research reviewed has dealt with waste water applications, this may however include publications that also cover other topics such as membrane fabrication or fouling studies that have been applied to waste water applications. Waste water applications total some 18.30%

of the papers reviewed, the trend is then: Pharmaceutical and biotechnology (14.04%), economics and design (13.72%), membrane modification (12.83%), solvent nanofiltration (11.25%), membrane fabrication (10.52%), desalination (8.94%), fouling studies (7.83%), modelling (6.78%), reviews (5.47%) and food (2.52%). Given that waste water applications and desalination could be grouped together as ‘water processing’ then this combined subject area is the predominant area of research interest and represents some 27.24% of publications, i.e. a quarter of all published nanofiltration research. Similarly, given that membrane modification is a subset of membrane fabrication, the combined total for this subject area becomes 23.35% of papers and is the second most significant subject area. Thus, water processing and membrane fabrication represent more than a half of all research interest in nanofiltration in terms of direct publications.

The data illustrates that nanofiltration has a wide range of applications, but research trends are more focussed in certain areas. For example, the largest single industrial application for nanofiltration seen in this review is that of water applications, both waste treatment and desalination. The water industry has used membranes for a considerable period of time and has a great deal of capital invested in the technology. However, for clean water production, nanofiltration is replacing or working alongside reverse osmosis which provides the cost benefit of lower pressure operation. Retrofitting in this sense is simple and is in essence replacement of the membranes only. Thus, research is clearly being conducted as inclusion of NF technologies is a straightforward task and the cost benefit/process improvement can easily be exploited. By contrast, the food industry is the lowest observed area of research found in this review. Parallel to the water industry, the food industry has used membranes for a considerable period of time and therefore one could easily expect similar levels of research. However, in this sector the membrane applications utilised have been predominantly microfiltration and ultrafiltration (e.g. removal of bacteria from products [5]). Retrofitting to include NF processes for this

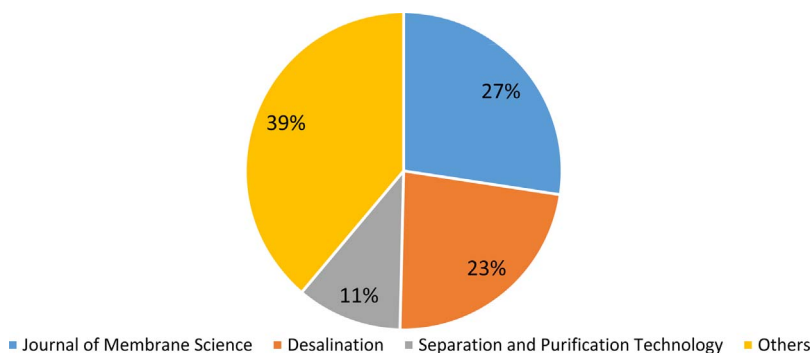


Fig. 2. The major journals publishing articles related to nanofiltration.

Download English Version:

<https://daneshyari.com/en/article/4909983>

Download Persian Version:

<https://daneshyari.com/article/4909983>

[Daneshyari.com](https://daneshyari.com)