



Nanofiltration membranes review: Recent advances and future prospects



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HIGHLIGHTS

- State-of-the-art overview of NF membranes and its approach on membrane fabrication and modification
- The trend and progress in the development and application of NF membranes over the past 5 years
- Fouling and fouling mitigation in the application of NF membrane
- Future direction in NF membrane development

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ABSTRACT

Nanofiltration (NF) membranes have come a long way since it was first introduced during the late 80's. With properties in between those of ultrafiltration (UF) and reverse osmosis (RO), NF membranes have been used in many interesting applications especially in water and wastewater treatment and desalination. Other applications include those in pharmaceutical and biotechnology, food and non-aqueous types of application. This review will comprehensively look at the recent advances in NF membranes research. Significant development has taken place in terms of the fundamental understanding of the transport mechanism in NF membranes. This has been translated into predictive modeling based on the modified extended Nernst–Planck equation. Similarly various methods have been used to fabricate improved NF membranes especially through interfacial polymerization incorporating nanoparticles and other additives, UV grafting/photografting, electron beam irradiation, plasma treatment and layer-by-layer modification. New applications were also explored in many industries. However fouling is still a prevalent issue that may hinder successful application of NF membranes. Efforts towards NF fouling prevention and mitigation have also been reported. The review ends with several recommendations on the future prospect of NF membranes research and development.

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1. Introduction

Nanofiltration (NF) membranes have come a long way since it was first recognized in the late 80's. With properties in between ultrafiltration (UF) and reverse osmosis (RO), NF membranes possess pore size typically of 1 nm which corresponds to molecular weight cut-off (MWCO) of 300–500 Da. NF membranes in contact with aqueous solution are also slightly charged due to the dissociation of surface functional groups or adsorption of charge solute. For example, polymeric NF membranes contain ionizable groups such as carboxylic groups and sulfonic acid groups which result in charged surface in the presence of

a feed solution. Similar to RO membranes, NF membranes are potent in the separation of inorganic salts and small organic molecules. Key distinguishing characteristics of NF membranes are low rejection of monovalent ions, high rejection of divalent ions and higher flux compared to RO membranes. These properties have allowed NF to be used in niche applications in many areas especially for water and wastewater treatment, pharmaceutical and biotechnology, and food engineering. Some commercial membranes, together with their properties and top layer composition as specified by the manufacturer are given in Table 1. Various aspects of NF membranes have been covered in a few review papers [1,2] while Schäfer et al. [3] have written a comprehensive

Table 1
Commercial nanofiltration membranes with specification of the manufacturers.

Membrane	Manufacturer	MWCO (Da)	Maximum temperature (°C)	pH range	Stabilized salt rejection (%)	Composition on top layer
NF270	Dow Filmtec ^a	200–400	45	2–11	>97%	Polyamide thin-film composite
NF200	Dow Filmtec ^a	200–400	45	3–10	50–65% CaCl ₂ 3% MgSO ₄ 5% Altrazine	Polyamide thin-film composite
NF90	Dow Filmtec ^a	200–400	45	3–10	85–95% NaCl >97% CaCl ₂	Polyamide thin-film composite
TS80	TriSep ^b	150	45	2–11	99%	Polyamide
TS40	TriSep ^b	200	50	3–10	99%	Polypiperazineamide
XN45	TriSep ^b	500	45	2–11	95%	Polyamide
UTC20	Toray ^c	180	35	3–10	60%	Polypiperazineamide
TR60	Toray ^c	400	35	3–8	55%	Cross-linked polyamide composite
CK	GE Osmonics ^d	2000	30	5–6.5	94% MgSO ₄	Cellulose acetate
DK	GE Osmonics ^d	200	50	3–9	98% MgSO ₄	Polyamide
DL	GE Osmonics ^d	150–300	90	1–11	96% MgSO ₄	Cross-linked aromatic polyamide
HL	GE Osmonics ^d	150–300	50	3–9	98% MgSO ₄	Cross-linked aromatic polyamide
NFX	Synder ^e	150–300	50	3–10.5	99% MgSO ₄ 40% NaCl	Proprietary polyamide thin-film composite
NFW	Synder ^e	300–500	50	3–10.5	97% MgSO ₄ 40% NaCl 20% NaCl	Proprietary polyamide thin-film composite
NFG	Synder ^e	600–800	50	4–10	50% MgSO ₄ 10% NaCl	Proprietary polyamide thin-film composite
TFC SR100	Koch ^f	200	50	4–10	>99%	Proprietary thin-film composite polyamide
SR3D	Koch ^f	200	50	4–10	>99%	Proprietary thin-film composite polyamide
SPIRAPRO	Koch ^f	200	50	3–10	99%	Proprietary thin-film composite polyamide
ESNA1	Nitto-Denko ^g	100–300	45	2–10	89%	Composite polyamide
NTR7450	Nitto-Denko ^g	600–800	40	2–14	50%	Sulfonated polyethersulfone

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