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Roles of Nanofiltration in Water Purification

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Nanofiltration (NF) is a pressure-driven membrane process with a wide range of performance characteristics between RO and UF. NF membranes offer high rejection of salts of divalent anions as well as organics having a molecular weight above 200. Recently, NF has attracted the attention of municipalities due to its broad spectrum of separation capability. It involves natural organic matter (NOM) and color removal, disinfection by-product (DBP) precursor removal, membrane softening (MS) for hardness removal, and synthetic organic chemicals (SOC) removal. To meet more stringent regulations for drinking water and wastewater discharge, NF technologies increasingly have been playing important roles.
Key words: nanofiltration, membrane separation, membrane softening, disinfection by-product, natural organic matter

1. INTRODUCTION

In recent years contamination with organic micropollutants such as dioxin, VOC, and pesticides is becoming an big issue in various water treatment fields. Although the existing technology utilizing coagulation and media filtration is well established and reliable, with advancements of industrial and agricultural activities it is becoming difficult for this conventional technology to remove such contaminants. To meet more stringent regulations for drinking water and wastewater discharge, several membrane filtration technologies increasingly have been playing more important roles. This symposium explains in detail water purification by Nanofiltration (NF).

2. NANOFILTRATION MEMBRANES

Nanofiltration (NF) is a pressure-driven membrane process with a wide range of performance characteristics between RO and UF. NF membranes offer high rejection of salts of divalent anions as well as organics having a molecular weight above 200. In the early 1980's, several thin-film composite type of NF membranes were developed. Since then NF technology has been widely applied in a variety of applications including municipal and industrial water treatment and food processing. Table 1 lists the commercially available spiral wound 8 inch elements with the manufacturer's Internet web site address.

Table I Performance of commercial 8 inch spiral wound NF elements

Membrane Manufacturer	Internet Web Site	Element Designation	NaCl Rej. (%)	$MgSO_4$ Rej. (%)	Flow Rate (m^3/D)	Test Conditions		Membrane Material
						Pres. (MPa)	Feed	
Desalination Systems	osmonics.com/	DS-5 DK8040F		98	30.2	0.69	2000 ppm $MgSO_4$	Proprietary thin-film
		DS-5 DL8040F		96	38.6	0.69	2000 ppm $MgSO_4$	
		DS-51 HL8040F		98	38.2	0.69	2000 ppm $MgSO_4$	
FilmTec	dow.com/liquidseps/	NF70-400	75	min. 95	47	0.48	2000 ppm $MgSO_4$	Cross-linked polyamide thin-film composite
		NF90-400	90	min. 95	39	0.48	2000 ppm $MgSO_4$	
		NF200B			27.7	0.48	500 ppm $CaCl_2$	
		NF45	30-70	min. 98	28.0	0.90	2000 ppm $MgSO_4$	
Fluid Systems	fluid-systems.com/	TFS®S-8921S	85		25.0	0.55	500 ppm NaCl	Polyamide
		TFS®S-8921S-400	85		30.3	0.55	500 ppm NaCl	
Hydranautics	membranes.com/	ESNA1	80 Ave.		41.6	0.52	500 ppm NaCl	Composite polyamide
		ESNA2	60 Ave.		56.8	0.52	500 ppm NaCl	
TriSep	trisep.com/	8040-TS40-TSA	-	98	30.3	0.69	500 ppm	Aromatic polyamide
		8040-TS80-TSA	92	98	30.3	0.69	500 ppm	
Nitto Denko	nitto.co.jp/	NTR-729HF	92	99	36	1.0	1500 ppm NaCl	Polyvinyl alcohol derivative
		NTR-7250	60	99	60	2.0	2000 ppm NaCl	Polyvinyl alcohol derivative
		NTR-7450	51	32	52	1.0	2000 ppm NaCl	Sulfonated polysulfone
		NTR-7410	15	9	100	1.0	2000 ppm NaCl	Sulfonated polysulfone
Toray	toray.co.jp/	SU-620	55		18.0	0.34	500 ppm NaCl	Polyamide composite
		SU-220S		99	40.0	0.74	500 ppm $MgSO_4$	

Internet Web Site Address : http://www.________.com/

3. MEMBRANE ROLES IN POTABLE WATER TREATMENT

Due to more stringent regulations in drinking water, membrane separation has been playing an increasingly important role. There are four general categories of crossflow membrane filtration: MF, UF, NF, and RO. The role of these membrane technologies in municipal water supply is summarized in Figure 1. Feed water supply contains a wide variety of contaminants which have to be removed. MF/UF can remove macromolecules and micro particles which include humic substances, microbials, colloids, and silt. RO can be used to remove lower molecular weight substances such as pesticides and harmful ions such as nitrate, arsenic, and lead. Recently, NF has attracted the attention of municipalities due to its broad spectrum of separation capability. NF involves:

- Natural organic matter (NOM) and color removal
- Disinfection by-product (DBP) precursor removal
- Membrane softening (MS) for hardness removal
- Synthetic organic chemicals (SOC) removal

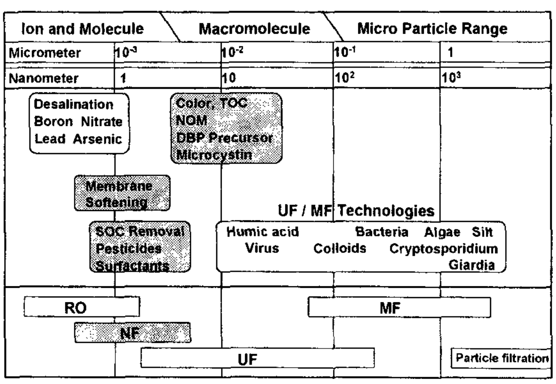

Fig. 1 Membrane roles in municipal water treatment

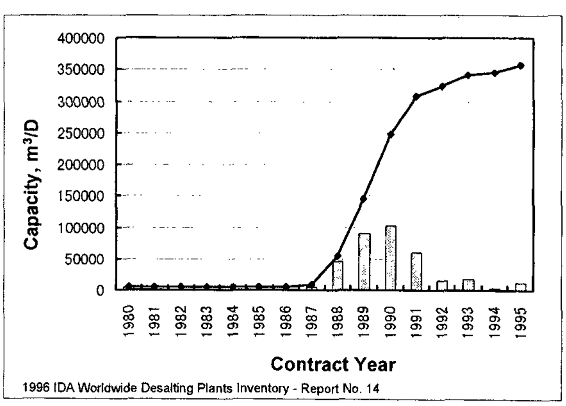

Fig.2 Membrane softening plants in the U.S.

4. SOFTENING BY NF

Nanofiltration is sometimes referred to as membrane softening. NF membranes have been used for hardness reduction or softening along with THM precursor removal. It was said that the idea of membrane softening was first proposed by a Florida based OEM in 1976. However, this membrane technology was not in wide spread use until after 1984 when a three month pilot study proved the effectiveness (at very low pressures) of composite polyamide NF membrane. After the extensive research and pilot tests, the number of municipal water treatment facilities using NF has dramatically increased as shown in Figure 2. Beside softening, recently several municipalities in Europe have put NF plants into operation to remove high levels of sulfate.

5. NATURAL ORGANIC MATTER (NOM) REMOVAL

Another major focus of NF technology is for NOM removal. NF has proven effective in THM precursor removal. Such organic removal is critically important in the U.S. The Information Collection Rule (ICR) was published on May 14, 1996. It requires large public water systems to conduct either bench- or pilot-scale testing of advanced treatment techniques including NF. Examples of performance of NF70 on Florida groundwater are shown in Table 2. NF70 shows high THM precursor rejection with the lower operating pressure of 60 psig.

Table II Membrane performance: groundwater near West Palm Beach, FL

Membrane	Pressure PSIG	Recovery %	Rejection, % THM Precursor		DOC*		Color		TH**	
			AID+	VOG++	AID	VOG	AID	VOG	AID	VOG
BW30	190	60	97		96	98	97	99	96	92
NF70	60	65	96		90	93	97	98	70	67
UF (2000)***	100	80	56		40	57	60	65	13	5

* DOC = Dissolved organic carbon
** TH = Total hardness as ppm as $CaCO_3$
*** UF = Ultrafiltration membrane with nominal MW cutoff 2000 (GIO DSI)
\+ AID = Water from ACME Improvement District
\++ VOG = Water from Village of Golf

Feed water data:

	Temp. °C	TDS mg/L	THM Precursor mg/L	DOC mg/L	Color CPU	TH ppm as $CaCO_3$
AID	25	490	.961	15	35	332
VOG	25	490	—	14.7	52	246

From Taylor etal 1987

6. SYNTHETIC ORGANIC CHEMICALS (SOC) REMOVAL

The drinking water standard for pesticides is 0.1 μg/l in the countries of the EC; in addition the EC requires that the total concentration of pesticides and related compounds does not exceed 0.5 μg/l. So several researchers have evaluated the separation characteristics of NF membranes for these components.

CONCLUSION

In this paper several advantages of NF technologies have been described. However, it should be noted that membrane technology does not solve all the water treatment problems encountered in municipalities. Membranes can provide effective and highly optimised solutions when integrated with conventional technologies such as coagulation, sand filtration, and activated carbon treatments. Finally it may be worth while mentioning that the large NF plant (140,000 m^3/D) for treating surface water is now being constructed in the suburbs of Paris.

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