Improving Membrane Prefiltration for Ultrapure Water Production

Lydall Filtration and Separation
134 Chestnut Hill Road
Rochester, NH 03866
Phone: 603-332-4600
Fax: 603-330-3023
Email: info@Lydall.com

Abstract

The production of ultrapure water for process industries generally requires the use of reverse osmosis membranes. RO membranes are prone to fouling if incoming water is high in contaminants. The stability and reliability of membrane systems varies due to inadequate, improper or sporadic pretreatment. Adequately treated feed water will ensure consistent product quality, minimal downtime and long membrane life. When consistent feed water, that is low in contaminants, is fed to an RO process, the unit can run for years without problems.

The performance of RO membrane systems is directly related to the type and level of impurities present in the feed water. The quality of water entering a plant can vary tremendously due to source and seasonality. Feed water can be sourced from a municipal plant, surface waters from lakes, reservoir or streams, ground water and recycled water from reject streams and waste water. Each source has different contaminant types and levels and may require different pretreatment systems to ensure a high quality feed water.

Understanding the type and quality of incoming water is critical to determining the correct pretreatment system. The major contaminants may be present in dissolved, suspended or colloidal form. Feed water characteristics that are important include; total suspended solids (TSS), total organic carbon (TOC), colloidal mater (which can be measured as SDI) and residual chlorine.

There are many different types of filter media that can be used for membrane pretreatment. The types of media vary by materials of construction, processing method and performance characteristics. This paper will discuss the different types of wetlaid, drylaid and membrane media for RO prefiltration and compare their methods of construction, performance and cost.

Keywords: Nonwoven, Prefiltration, Membrane, Reverse Osmosis, Microfiltration, Ultrafiltration, Nanofibers, Microfiberglass, Meltblown

Introduction

The performance of RO membrane systems is directly related to the type and level of impurities present in the feed water. The quality of water entering a plant can vary tremendously due to source and seasonality. Feed water can be sourced from a municipal plant, surface waters from lakes, reservoir or streams, ground water and recycled water from reject streams and waste water. Each source has different contaminant types and levels and may require different pretreatment systems to ensure a high quality feed water. Adequately treated feed water will ensure consistent product quality, minimal downtime and long membrane life. When consistent feed water, that is low in contaminants, is fed to an RO process, the unit can run for years without problems. Ten years ago, the expected service life of an RO membrane element was 3 – 5 years. With improvements in membrane performance, regular cleaning cycles and properly designed pretreatment systems, membrane elements are now expected to run for 5 – 7 years with many running for ten years.

Feed water from a municipal system may be acceptable for drinking water but needs additional pretreatment before feeding an RO membrane. Surface water can vary widely with geography and seasonality and need pretreatment systems that can accommodate dramatic changes in water quality. Ground water generally provides better water quality and less pretreatment for an RO system but can vary with geography and water table level.

Understanding the type and quality of incoming water is critical to determining the correct pretreatment system. The major contaminants may be present in dissolved, suspended or colloidal form. Feed water characteristics that are important include; total suspended solids (TSS), total organic carbon (TOC), colloidal mater (which can be measured as SDI) and residual chlorine. A properly designed pretreatment system requires the generation of water quality data over the course of a year to adequately determine the fluctuations in contaminant type and level. Table 1 lists the typical feed water quality from a municipal source and the limits for a typical RO system.

Table 1

Parameter	Municipal Water	RO Feed Water
Turbidity (NTU)	0.2 – 5	< 1
TSS (mg/L)	0.5 – 2	< 1
TOC (mg/L)	1 – 10	< 5
SDI	3 – 12	< 3

Microfiltration (MF) membranes are frequently used as a pretreatment for RO systems. MF membranes are available in pleated cartridge or hollow fiber formats at a range of efficiencies. They can be run in normal or cross flow mode and many hollow fiber formats are backflushable. The development of backflushing hollow fibers has made membrane based water filtration an economic process for many municipalities. Feed water pretreated with MF membranes can reduce SDI levels below 3 and remove bacteria at 3 – 4 log levels. Crossflow MF treatment can remove precipitated contaminants such as hardness silica and metals. Based on the raw water quality, MF membranes may not need additional upstream prefiltration.

Microfiltration Membranes

Microfiltration membranes are produced by a wide variety of processes. The most common process is to dissolve a polymer in a solvent and produce a liquid film on a support material. The solvent is removed by evaporation or dilution in a nonsolvent and the polymer is precipitated forming a porous structure. The concentration of polymer in the solution and the rate of precipation determine the degree of porosity and the pore size distribution. Microfiltration membranes are produced with efficiencies from 0.05 um to 5 um.

Nonwoven Media

Nonwoven media can be classified into two distinct types based on their method of formation. The first method is a dry laid process, which includes carded, needled, spunbond and meltblown media. The second process uses a wet laid formation, which is generally done on a paper machine. Each process produces a media with unique properties that have advantages in different applications.

Dry laid processes generally produce media with nominal ratings that are low cost and have high dirt holding capacities. The nonwovens generally are produced with polyolefin, polyester or nylon polymers and fibers. Meltblown media are one of the most versatile nonwovens for liquid filtration and the only one that can achieve submicron filtration. Meltblown media is generally composed of a continuous network of self-bonded polypropylene, polyester or nylon microfibers produced with a controlled fiber uniformity and density. The resulting media has a uniform porosity, does not shed fibers and contains no binders, adhesives or surfactants. Meltblown media have nominal ratings from 1 μm to 50 μm and when calendered or laminated into composites can have sub micron and absolute ratings. Meltblown media can also be produced using high-purity FDA-acceptable polymers.

Meltblown media are produced by blowing a thermoplastic resin from an extruder die tip with air at a high velocity onto a substrate, belt or wire, which results in a self-bonded web with relatively fine fibers. Fibers produced in a meltblown operation are generally in the 4 – 20 μm range. Using very high airflow, meltblown fibers can be produced in the 2 – 5 μm range. Meltblown media have not generally been successful in finer filtration applications due to the relatively large fibers that are produced. Performance are outweighed by the higher cost. Figure 4 shows a typical meltblown media with 10 – 20 um fibers and a meltspun media with fibers < 0.5 um.

Another method of producing higher efficiency meltblown media is to hot calender the product. In this process the meltblown media is run between two heated steel rolls or a heated steel roll and a soft rubber roll with pressure. The calendering process compresses the fibrous structure and with enough heat and pressure can begin to form a microporous film. Calendering increases the efficiency of the media but also increases the pressure drop. Meltblown media can be calendered to absolute efficiencies below 1 μm. Figure 5 compares a lightly calendered and highly calendered media.

Wetlaid Media

Wetlaid media are generally produced on a paper machine and with cellulose, polymeric or glass fibers. It is common for media to be produced with one or more of the different fiber types. Microfiberglass media can be produced with the broadest range of filtration capability and efficiencies due to the wide range of fibers available. Wetlaid media can be made with nominal or absolute filter ratings. They typically contain binders which can have poor chemical and thermal resistance and high extractables when compared to air laid media. Wetlaid media can also be made using FDA compliant materials. New wetlaid media have begun to compete with MF membranes in many applications. High efficiency wetlaid media have equivalent efficiency as MF membranes but with significantly higher dirt holding capacity or life.

Performance

Submicron microglass, meltblown and membrane media with ratings in the range of 0.2 μm, 0.5 μm and 1.0 μm were tested for efficiency, clean water flowrate and dirt holding capacities. Microglass and MF membrane samples were available in 0.2 μm, 0.5 μm and 1.0 μm ratings. Calendered meltblown was only available in 0.6 μm and 1.0 μm ratings. Table 2 compares the media at each rating with their measured mean flow pore size (MFP). The microglass and meltblown media had similar MFP results at the same micron rating. The MF membrane samples had MFP values that were below the lower test level.

Table 2

Media Rating (μm)	MFP (μm)		
	Microglass	Meltblown	Membrane
0.2	1.1	1.5	3.5
0.5/0.6	NA	1.7	3.2
1.0	0.2	0.6	1.0

Each of the media samples was tested for efficiency with fluorescent latex beads at 0.4 μm, 0.8 and 3.0 μm. Based on the feed concentration and background noise the lower detection limit was 0.1% for the test. Figure 1 plots the retention of the three different rated microglass media. All three had high particle retention from 0.8 μm – 3.0 μm. There was a clear difference in efficiency between the three different rated media at 0.43 μm.

Figure 1

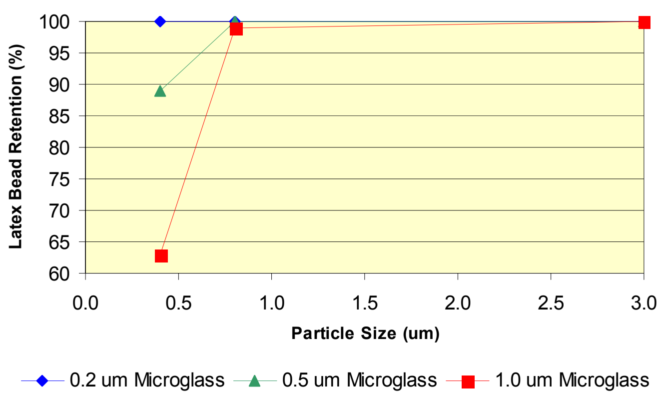


Figure 2 plots the retention of the meltblown media. The two different rated media show a significant difference in efficiency from 0.43 μm to 3.0 μm but neither sample have absolute efficiency over that range.

Figure 2

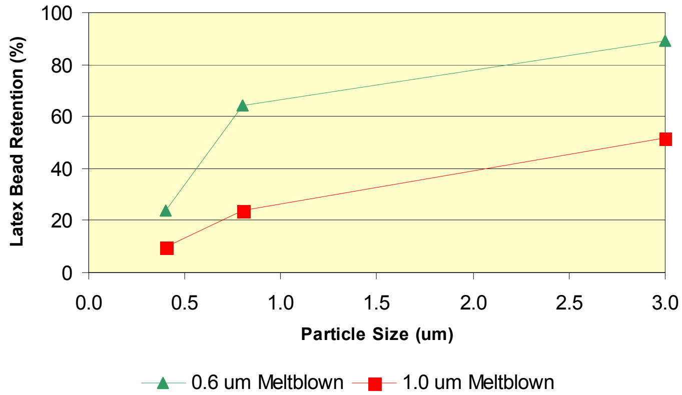


Figure 3 plots the retention of the three different rated MF membranes. The 0.2 and 0.5 micron rated membranes had high particle retention from 0.43 μm – 3.0 μm. The 0.8 μm rated membrane had high retention at 3.0 μm and poor retention at 0.43 μm and 0.8 μm.

Figure 3

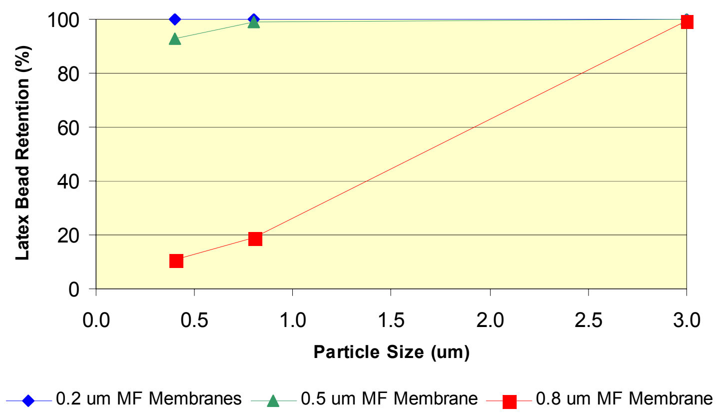


Figure 4 compares the latex bead retention of all the 0.5 μm rated media. The microglass media and the MF membrane samples both have high retention of particles from 0.4 μm to 3.0 μm. The meltblown media had low particle retention at 0.43 μm and nominal efficiency at 0.8 μm and 3.0 μm.

Figure 4

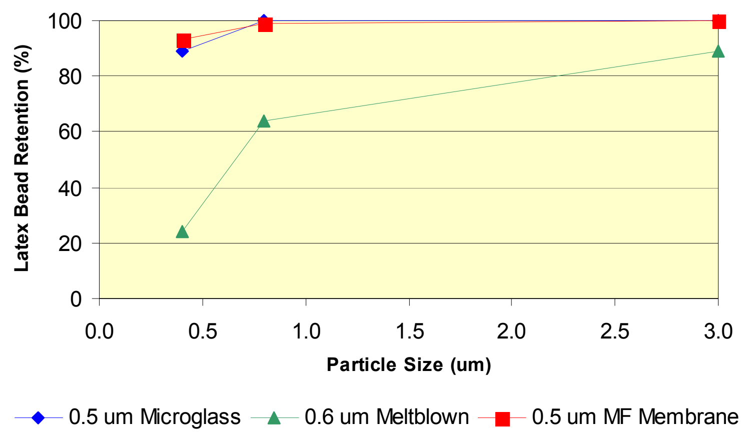
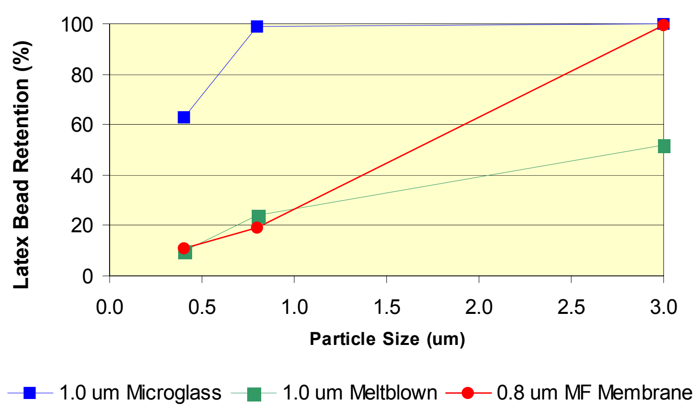


Figure 5 compares the latex bead retention of all the 0.8 µm – 1.0 µm rated media. The microglass media had high retention at 0.8 µm and larger. The meltblown media had low retention at 0.43 µm and 0.8 µm and nominal efficiency at 3.0 µm. The MF membrane had low efficiency at 0.43 µm and 0.8 µm and high efficiency at 3.0 µm.

Figure 5



Each of the media samples was tested for turbidity reduction using AC fine test dust. The fine test dust has a mean particle size of 19 µm and a distribution of particles from submicron to eighty micron. Based on the feed concentration and background noise the lower detection limit was 0.2% for the test. Figure 6 plots the retention of the three different media at each micron rating. The 0.2 micron rated media were fully retentive of the AC fine test dust. The meltblown had the highest efficiency at 0.5 µm and 1.0 µm. The MF membrane had high retention at 0.5 µm and nominal efficiency at 0.8 µm. The microglass media had lowest efficiency at 0.5 µm and 1.0 µm because the material is a depth media and not a surface filter like the meltblown and MF membrane which surface load improving efficiency.

Figure 6

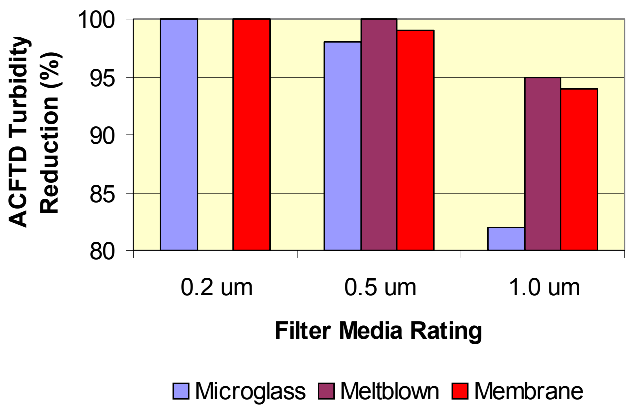


Figure 7 plots the clean water flux for each of the samples. The microglass media has significantly higher liquid permeability than the meltblown and the membrane media.

Figure 7

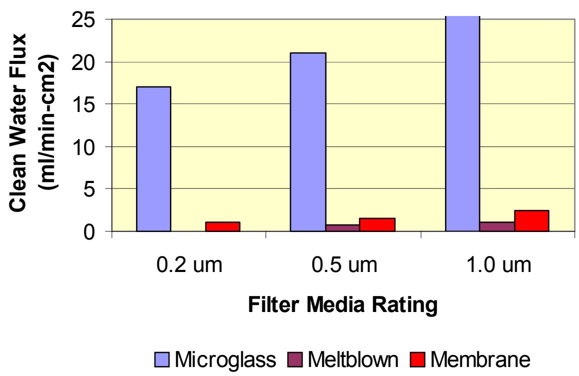


Figure 8 plots the dirt holding capacity of each of the media types and ratings. The microglass media has significantly higher dirt holding capacity than the other two which are surface filters.

Figure 8