DEMYSTIFYING MEMBRANE PRETREATMENT

By Anthony Wachinski & Jay Garcia

Evaluating pretreatment schemes to maximize efficiency and reduce costs

Membrane pretreatment is a popular topic in the industry—a topic that can sometimes cause confusion. The intent of this article is to clarify the term "membrane pretreatment" and describe its impact on membrane performance. Membranes used in water and wastewater treatment applications are categorized as either "high-pressure" or "diffusive membranes" (reverse osmosis [RO] and nanofiltration [NF]), or as "low-pressure" (ultrafiltration [UF] and microfiltration [MF]). Each requires pretreatment to perform optimally.

PRETREATMENT RULES OF THUMB

Pretreatment is indicated when:

- The overall lifetime cost of the plant without pretreatment is more expensive than the cost of the plant with pretreatment. These costs include equipment capital costs, installation and construction costs, and annual energy, chemical (cleaning and pretreatment chemicals) and labor amortized over design life.
- It is required by customer or regulator (e.g., the Missouri Department of Environmental Health requires conventional treatment on all water plants.)
- Design flux (target flux) cannot be achieved on exisiting water quality.
- Flux maintenance and clean-in-place frequency affect design recovery, creating a less-than-targeted value due to turbidity spikes, TOC, suspended solids and algae.
- Oxidation of soluble species (e.g., iron, manganese and arsenic) is required.
- MF alone cannot meet all treatment objectives (e.g., color, TOC and virus removal greater than 0.5 log).
- Non-compatible contaminants such as cationic polymers, oils (e.g., fish oils) and "sticky solids" (e.g., pine oils) are present in the feedwater.

ARTICLE SUMMARY

Challenge: NF/RO and MF/UF membrane systems require pretreatment to function properly and efficiently.

Solution: Mechanical and/or chemical conditioning pretreatment systems provide high-quality feed water for NF and RO membranes.

Conclusion: Membrane treatment systems work most efficiently and cost-effectively with application-specific pretreatment.

Solids Separation

Hollow-fiber MF and UF systems are designed specifically to remove turbidity and suspended solids, but large particulate matter can damage or plug the membrane fibers. For low-pressure systems, a backwashable strainer (typically 300-micron) is necessary and typically included in the scope of supply of the membrane system manufacturer. While this covers the great majority of applications, further coarse treatment (e.g., sedimentation or dissolved-air flotation) may be required for some "dirtier" waters. Furthermore, hollow-fiber MF/UF systems that are operated in an inside-out mode are more susceptible to fiber plugging and therefore may require finer prefiltration.

NF and RO processes utilize non-porous semipermeable membranes that cannot be backwashed. These almost always exist in a spiral-wound configuration that requires much finer prefiltration to minimize exposure of the membranes to particulate matter of any size. Spiral-wound modules are highly susceptible to particulate fouling, which can reduce system productivity, create operational problems and significantly reduce membrane life.

Until five years ago, the design philosophy followed that if the feedwater had a turbidity less than approximately 1 NTU or a silt density index (SDI) less than approximately 5, membranes would run efficiently. Today, with greater collective experience, we know that an RO system runs significantly better if the feedwater SDI is 3 or less, with less than 2 fast becoming the standard goal. Even today, many RO and NF membrane systems are pretreated with a combination of multimedia filtration and cartridge filters with ratings ranging from about 5 to 20 µm. Depending on feedwater quality, this pretreatment scheme may work well. This may not, however, be the most optimal pretreatment in all cases. Many times cartridge filter changeouts are frequent and expensive and/or the SDI goal of 3 cannot be achieved. In those cases, a more rigorous method of particulate removal is required.

Best practices for NF/RO systems now dictate a pretreatment process of MF/UF followed by a pleated disposable filter used as a guard filter with infrequent changeouts. This type of treatment scheme is commonly known as an integrated membrane system (IMS). With an IMS treatment scheme, the MF/UF provides consistently high-quality water (typical SDI less than 2) to the NF/RO with respect to particulate matter, regardless of changes in raw water quality. This is due to the fact that low-pressure systems inherently are able to handle raw water variations. Moreover, incorporating a high-crystalline polyvinylidene difluoride (PVDF) MF system assures that there are no fiber breakages (i.e., integrity breaches that could compromise the NF/RO system). IMS systems also offer the benefit of integrated plant control via one programmable logic controller designed to optimize the full process.

Chemical Conditioning

While we have only discussed pretreatment as a way to filter large solids off the membranes, many systems require a different method of pretreatment to meet filtration goals. Chemical conditioning is used for a number of pretreatment purposes, including pH adjustment, disinfection, biofouling control, scale inhibition, coagulation and oxidation. Some type of chemical conditioning almost always is used with NF/RO systems, most often the addition of an acid (to reduce the pH) or a proprietary scale inhibitor recommended by the membrane manufacturer to prevent the precipitation of sparingly soluble salts (e.g., calcium carbonate, barium sulfate, strontium sulfate or silica species) on the membrane.

Software programs that simulate NF/RO scaling potential based on feedwater quality are available from various membrane manufacturers. In some cases, such as for NF and RO membranes manufactured from cellulose acetate, the feedwater pH must be adjusted to maintain the pH within an acceptable operating range to minimize the hydrolysis (chemical deterioration) of the membrane. The addition of chlorine or other disinfectants also may be used as pretreatment for primary disinfection or to control biofouling. Because NF/RO membrane materials are easily damaged by oxidants, it is important that any disinfectants added upstream are neutralized with a reducing agent prior to contact with them.

A number of different chemicals may be added as pretreatment for MF or UF depending on the system's treatment objectives. For example: Lime and soda ash are added for softening applications, and coagulants are added to enhance removal of total organic carbon (TOC) with the intent of minimizing load to the NF/RO or to meet drinking water regulations. Disinfectants are applied for either primary disinfection or biofouling control, and various oxidants can be used to oxidize metals such iron and manganese for subsequent filtration. Ferric chloride is added to remove arsenic to below 10 parts per billion using UF or MF membranes.

As with conventional media filters, presettling may be used in conjunction with pretreatment processes such as coagulation and lime softening. While an MF/UF system may be able to operate efficiently with the in-line addition of lime or coagulants, direct coagulation pre-settling in association with these pretreatment

The custom MF system at West Elgin, Ontario, Canada, uses high-crystalline PVDF membranes.

processes can enhance membrane flux and increase system productivity. It achieves this by reducing the solids loading, thus minimizing backwashing and chemical cleaning frequency. Usually the overall lifetime economics of the system can be used to make the decision of whether or not to use pre-settling. This economic evaluation takes into account the capital costs of the systems as well as membrane replacement costs (after 10 years of service life), chemical costs, energy costs, disposal (chemical and non-chemical waste) and labor.

It is important with any form of chemical pretreatment to understand whether any chemical under consideration for use is compatible with the membrane material. In addition to irreversible fouling and physical damage to the membranes, the use of an incompatible chemical may void a manufacturer's warranty. Some chemicals (e.g., oxidants) can be quenched upstream, while others (e.g., coagulants and lime) cannot be removed prior to membrane exposure. In general, most NF/RO membranes and some MF/UF membranes are not compatible with disinfectants and other oxidants.

High-crystalline PVDF MF membranes created with the thermally induced phase separation (TIPS) manufacturing method generally are the most oxidant-resistant in the industry, handling high concentrations of chlorine, potassium, permanganate, hydrogen peroxide and other common treatment and cleaning chemicals. This characteristic, combined with high mechanical strength, makes them suitable for almost all water and wastewater applications.

Furthermore, certain types of both MF/UF and NF/RO membranes require operation within a certain pH range. Coagulants and lime are incompatible with many NF/RO membranes, but typically with most types of MF/UF membranes. Polymers are incompatible with NF/RO membranes, and generally are not compatible with MF/UF membranes either—though this depends to some degree on the charge of the polymer relative to the charge associated with the membrane. Caution always should be used when developing any process with the words "membranes" and "polymers."

Conclusion

Pretreatment is necessary for all membrane system operations. This includes mandatory mechanical separation to reduce solids loading on both low- and high-pressure membranes. At times, it also includes chemical pretreatment to optimize the system process and to meet treatment goals such as TOC or arsenic removal. Moreover, pretreatment schemes such as pre-settling always should be evaluated to ensure the lowest overall cost of plant ownership. Pre-settling can reduce the solids loading, which will reduce the amount of membrane required. In some cases, this may provide for a more economical solution. WWD

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