Membrane Cleaning Guide
Water Application Elements

The following are general recommendations for cleaning TRISEP® thin-film composite reverse osmosis (RO) and nanofiltration (NF) elements used in water applications. These recommendations may be implemented for elements being used in process application systems as well as thin film composite ultrafiltration (UF) and microfiltration (MF) elements. For additional information on cleaning elements used in specific process applications, please see MANN+HUMMEL Water & Fluid Solutions' other various Cleaning Guides. For information on cleaning cellulose acetate elements used in water applications, please refer to **Membrane Cleaning Guide – Cellulose Acetate Elements** (TSG-C-005).

MANN+HUMMEL Water & Fluid Solutions recognizes that specific Clean in Place (CIP) procedures for water application elements will vary from system to system based on the unique requirements of individual end users. The guidelines provided here should serve as general instructions regarding the limits of TRISEP elements with commonly used membrane cleaning procedures. For questions regarding compatibility of specific cleaning regimens with TRISEP products, please contact MANN+HUMMEL Water & Fluid Solutions Technical Service.

INTRODUCTION

During operation, the surface of a membrane is subject to fouling by mineral scale, biological matter, colloidal particles and insoluble organic constituents. The term "fouling" includes the build-up of any type of material on the membrane surface, including mineral scaling. Membrane surface fouling results in lower permeate flow rate, increased pressure drop between the feed and concentrate, and/or higher solute passage.

WHEN TO CLEAN

Elements should be cleaned when one or more of the below have been met:

- Normalized* permeate flow drops 10%
- Normalized salt passage increases 10%
- Normalized pressure drop increases 10 – 15%

*Normalizing performance data is helpful in determining when it is necessary to clean. Sometimes a drop in permeate flow, an increase in salt passage or an increase in pressure drop is noticed for alternative reasons (i.e. changes in temperature). It is recommended to measure and record permeate flow, salt passage and pressure drop across each stage in the system because a malfunction in pretreatment, temperature or pressure control, or a change in recovery can result in a change in product water output, salt passage and pressure drop. If such a problem is observed, these causes should be considered first because the elements may not require cleaning. MANN+HUMMEL Water & Fluid Solutions offers a Normalization Spreadsheet, which can be downloaded from our website.

SAFETY PRECAUTIONS

When using the chemicals indicated below, please follow these accepted safety practices:

1. Always wear eye protection. In the case of handling corrosive chemicals, wear full-face masks and protective clothing. Consult the chemical manufacturer for detailed information about safety, handling and disposal.
2. When preparing cleaning solutions, ensure that all chemicals are dissolved and well mixed before circulating the solutions to the elements.
3. High-quality water must be used for flushing, cleaning and disinfecting TRISEP membranes. See Water Quality.
4. Cleaning chemicals will be present on both the permeate and concentrate sides of the membrane immediately after cleaning. Properly flush the system prior to operation with the feed stream and divert permeate to drain for at least 30 minutes or until the water is clear when starting up after cleaning.

CLEANING TIPS

1. It is strongly recommended to clean the stages of the membrane system separately as to avoid having the removed foulant from one stage entering the next.
    a. For multi-stage systems, while each stage should be cleaned separately, the flushing and soaking operations may be done simultaneously in all stages. High-flow recirculation, however, should also be carried out separately for each stage so the flow rate is not too low in the first stage or too high in the last. This can be accomplished either by using one cleaning pump and operating one stage at a time, or by using a separate cleaning pump for each stage.
    b. Fresh cleaning solution needs to be prepared when the cleaning solution becomes turbid and/or discolored.
2. Fouling and scaling of elements often occur simultaneously. Therefore, MICRODYN-NADIR recommends performing an alkaline cleaning followed by an acid cleaning.
    a. Acid cleaning should only be the first cleaning step if it is known that only calcium carbonate or iron oxide/hydroxide is present on the membrane elements. This is because acid cleaners typically react with silica, organics and biofilm present on the membrane surface which may cause an additional decline in membrane performance. Sometimes, an alkaline cleaning can restore this decline, but most times, an extreme cleaning is necessary. Extreme cleanings are typically performed at pH and temperature conditions that are outside the membrane manufacturer's guidelines or by using cleaning chemicals that are not compatible with the membrane elements. These types of extreme cleanings should be left as a last resort as they can result in membrane damage.
    b. If the system suffers from colloidal, organic fouling or biofouling in combination with calcium carbonate, a two-step cleaning program is recommended: an alkaline cleaning followed by an acid cleaning. The acid cleaning may be performed when the alkaline cleaning has effectively removed the organic, colloidal fouling and biofouling.
3. Always measure the pH during cleaning. If the pH increases by more than 0.5 during acid cleaning, additional acid needs to be added. If the pH decreases by more than 0.5 during alkaline cleaning, more caustic should be added.
4. Long soak times are recommended while circulating the cleaning solution regularly to maintain the temperature (temperature should not drop more than 5°C). Add chemicals if the pH needs to be adjusted.
5. When cleaning or flushing the elements, be sure that the permeate valves always remain open. If the permeate valve is closed, the pressure on the permeate line will equalize to the feed pressure. This pressure is more than likely greater than the concentrate pressure and result in the permeate pressure being greater on the feed side of the tail element. This may lead to membrane delamination and performance failure.

ALKALINE CLEANING

Alkaline cleaners are used to remove organic fouling including biological matter, particulates/silt and silica.

1. Prepare cleaning solution with TriClean™ 214TF or TriClean™ 212TF*.
   **Note: TriClean™ 212TF is the powdered form of TriClean™ 214TF.*
2. Flush the system with chlorine-free permeate. See *Water Quality* below.
3. Fill the cleaning tank with water.
4. Add the cleaning solution to the tank and mix. Do not introduce the solution to the membrane system until thoroughly mixed.
5. Adjust the pH to 11 – 12 using additional chemical to increase the pH and acid as necessary to lower the pH. Use caution as high pH may damage membrane. See *Cleaning Temperature and pH Limits*.
6. Heat the cleaning solution to 35°C (95°F).
7. Send the cleaning solution through the membrane elements at a low flow rate (approximately half the flow rate listed in Table 5 in *Flow Rates* below) to drain until the water coming out of the elements is replaced by cleaning solution. If the

cleaning solution is dark and turbid, continue sending it through the elements to drain. It may be necessary to prepare additional cleaning solution in order to have sufficient cleaning solution available for the cleaning.

8. Recirculate the cleaning solution for 1 hour, checking pH regularly.
9. Shut down the pump and allow the membrane system to soak with cleaning solution for 1 hour (overnight soaks of 10 – 15 hours may be implemented for severe fouling). Maintain pH and temperature.
10. After soak, recirculate cleaning solution through membrane system again for 30 min at a high flow rate (approximately 1.5 times more than the flow rate listed in Table 5 in *Flow Rates*).
11. Repeat soak and recirculation steps if more cleaning is necessary.
12. Flush membrane system with clean water (see *Water Quality*) to drain until cleaning solution has been completely removed from the system (outlet and inlet pH should match).

ACID CLEANING

Acid cleaners are used to remove inorganic precipitates including carbonates, sulfates, iron and hydroxides. The following regimen uses TriClean™ 310 or TriClean™ 210, however other acids may be used for acid cleaning and in the pH range of 1 – 2.

1. Prepare cleaning solution with TriClean™ 310 or TriClean™ 210*.
   **Note: TriClean™ 210 is the powdered form of TriClean™ 310.*
2. Flush the system with chlorine free permeate. See *Water Quality* below.
3. Fill the cleaning tank with water.
4. Add the cleaning solution to the tank and mix. Do not introduce the solution to the membrane system until thoroughly mixed.
5. Adjust the pH to 2 – 3 using NaOH to increase the pH and additional chemical to lower the pH. Use caution as low pH may damage membrane. See *Cleaning Temperature and pH Limits*.
6. Heat the cleaning solution to 40 – 45°C (104 – 113°F).
7. Send the cleaning solution through the membrane elements at a low flow rate (approximately half the flow rate listed in Table 5 in *Flow Rates* below) to drain until the water coming out of the elements is replaced by cleaning solution. If the cleaning solution is dark and turbid, continue sending it through the elements to drain. It may be necessary to prepare additional cleaning solution in order to have sufficient cleaning solution available for the cleaning.
8. Recirculate the cleaning solution for 1 hour, checking pH regularly.
9. Shut down the pump and allow the membrane system to soak with cleaning solution for 1 hour (overnight soaks of 10 – 15 hours may be implemented for severe fouling). Maintain pH and temperature.
10. After soak, recirculate cleaning solution through membrane system again for 30 min at a high flow rate (approximately 1.5 times more than the flow rate listed in Table 5 in *Flow Rates*).
11. Repeat soak and recirculation steps if more cleaning is necessary.
12. Flush membrane system with clean water (see *Water Quality*) to drain until cleaning solution has been completely removed from the system (outlet and inlet pH should match).

CLEANING TEMPERATURE AND PH LIMITS

Temperature and pH adjustments both have a strong influence on the effectiveness of membrane cleaning. Generally, warmer temperatures and stronger pH adjustments result in better cleaning results. However, various material components within an element are limited in their ability to withstand the combination of temperature and pH. Table 1 below provides guidelines for acceptable pH and temperature limits for TRISEP® membranes.

TABLE 1. TEMPERATURE AND PH LIMITS BY MEMBRANE TYPE.

Membrane Type	pH Limits at 45°C (113°F)	pH Limits at 50°C (122°F)
Reverse Osmosis (RO)	1 – 12	2 – 11
Nanofiltration (NF)	1 – 12	2 – 11
Ultrafiltration (UF)	1 – 12	2 – 11
Microfiltration (MF)	1 – 12	2 - 11

HIGH AND LOW PH CLEANING SOLUTIONS

Depending on the fouling material, either a high pH or low pH solution should be used. High pH cleanings are effective on organic materials because the high pH promotes hydrolysis of organic species. Low pH cleanings are effective on inorganic materials because the low pH increases the solubility of inorganic species. Table 2 below provides commonly used acids and bases for high and low pH cleanings.

TABLE 2. COMMONLY USED ACIDS AND BASES FOR PH ADJUSTMENT.

Acid/Base	Typical Concentrations in Solution
Bases (NaOH)	0.05 – 0.1 wt%
Acids* (HCl, H_2SO_4, H_3PO_4, Citric)	0.1 – 0.2 wt%

* Certain nanofiltration membranes are sensitive to nitric acid. For NF systems in applications requiring frequent cleanings, it is recommended to use a phosphoric and nitric acid blend.

SPECIALTY CLEANERS

Other chemicals may be used in addition to the bases and acids listed above. Specialty cleaners also employ chelating agents, detergents and surfactants to promote effective membrane cleanings. Specialty cleaners should only be used if formulated specifically for membrane systems.

When selecting a chemical provider, be sure to purchase from reputable businesses with experience in membrane systems. Closely follow the recommendations provided by the supplier within the guidelines provided in this document. For questions regarding compatibility, be sure to contact MANN+HUMMEL Water & Fluid Solutions Technical Service prior to attempting any cleaning.

MEMBRANE DISINFECTION

Occasionally systems, particularly those operating on feed sources with high organic content, may require disinfection. Commonly used disinfectants and their compatibility with various TRISEP® membranes are listed in Table 3 below.

TABLE 3. COMMON DISINFECTANTS COMPATIBLE WITH TRISEP® MEMBRANES.

Disinfectant	Compatible Membranes
Hydrogen Peroxide – Peracetic Acid Mixtures*	RO, NF, UF, MF
Sodium Hypochlorite**	UF, MF, Cellulose Acetate (CA) RO & NF
Methylchloroisothiazolinone or DBNPA	RO, NF, UF, MF

* Please consult MANN+HUMMEL Water & Fluid Solutions' **Membrane Disinfection Guideline – Hydrogen Peroxide/Peracetic Acid Mixtures** (TSG-C-006).
** Please consult individual element data sheets for specific chlorine tolerances.

HOT WATER SANITIZATION

As an alternative to chemical disinfection many plants using process elements employ heat sanitization of their membrane systems. MICRODYN-NADIR manufactures a wide variety of RO, NF, UF, and MF membranes designed for sanitization with hot water. When sanitizing these membranes please refer to individual product data sheets for temperature and pressure limits.

WATER QUALITY

High quality water such as RO or NF permeate should be used for preparing cleaning solution mixtures (see Table 4). In addition, membrane elements should also be sanitized and rinsed with high quality water, preferably RO or NF permeate. Poor quality water can potentially react with cleaning compounds to precipitate sparingly soluble mineral and foulants within the cleaning mixture. Please note that disinfection processes involving hydrogen peroxide and peracetic acid mixtures also require water free of iron and other heavy metals to prevent catalyzing oxidation reactions on the membrane surface.

TABLE 4. RECOMMENDED CLEANING, SANITIZING, AND FLUSH WATER QUALITY.

Solute	Recommended Limit
Iron (Fe)	< 0.05 mg/L
Manganese (Mn)	< 0.02 mg/L
Aluminum (Al)	< 0.05 mg/L
Silica (SiO_2)	< 5.0 mg/L
Total Hardness as $CaCO_3$	< 50 mg/L as $CaCO_3$
Total Alkalinity as $CaCO_3$	< 50 mg/L as $CaCO_3$
Chlorine	0 mg/L
Turbidity	< 0.5 NTU
Silt	< 1 SDI

FLOW RATES

High fluid flow rates improve the effectiveness of cleanings by flushing foulants removed during the process from the membrane system. Recommended flow rates vary based on the diameter of the membrane elements being cleaned. Table 5 summarizes the recommended flow rates and cleaning pressures. Please note that pressure drop during cleaning should not be allowed to exceed 3.5 bar (50 psi) across a pressure vessel or 1 bar (15 psi) per installed element within a vessel. Operate cleaning at as low a pressure as possible in order to clean the membrane most effectively and without pushing foulant into the membrane.

TABLE 5. SUGGESTED FLOW RATES DURING CLEANING AND RINSING.

Membrane Diameter	Flow Rate per Vessel	Recommended Pressure	Maximum Pressure Drop
2.5”	0.7 – 1.2 m^3/hr (3 – 5 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)
3.8”	1.8 – 2.3 m^3/hr (8 – 10 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)
4.0”	1.8 – 2.3 m^3/hr (8 – 10 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)
6.3”	3.6 – 4.5 m^3/hr (16 – 20 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)
8.0”	7.0 – 9.1 m^3/hr (30 – 40 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)
8.3”	7.9 – 10.2 m^3/hr (35 – 45 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)
8.5”	7.9 – 10.2 m^3/hr (35 – 45 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)

A low flow rate should be used for the pre-soak recirculation. This flow rate would be about 50% less of what is shown in Table 5.

A high flow rate should be used for the post-soak recirculation. This flow rate would be about 50% more of what is shown in Table 5.

For extended soaks (10 – 15 hours), a very low flow may be used to maintain consistent temperature and pH throughout the duration of the soak. This flow rate would be about 10% of what is shown in Table 5.

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