Pretreatment
Phosphate Scale

The following are general recommendations for controlling phosphate scale in systems using reverse osmosis (RO) and nanofiltration (NF) elements. For additional information on pretreatment or cleaning elements, please see MANN+HUMMEL Water & Fluid Solutions' Pretreatment and Cleaning Guides or contact MANN+HUMMEL Water & Fluid Solutions Technical Service.

INTRODUCTION

Scaling is when sparingly soluble salts precipitate and deposit on the surface of a membrane element. The solubility of phosphate is low and may lead to scale formation on the membrane surface where the salts are most concentrated. This typically affects the elements in the last stage first and then gradually affects the stages upstream.

With dwindling water supply, regulators have begun to impose tighter restrictions on water use and increased penalty rates for waste disposal. Such restrictions have encouraged industrial plants to reuse wastewater and operate their systems at higher recoveries, presenting a challenge for systems originally designed to operate at low recovery. Because of this, phosphate scaling has occurred more frequently. In municipal wastewater, phosphate levels can range from 1 ppm to more than 20 ppm depending on the treatment process, resulting in calcium phosphate scaling in particular.

Phosphorus is a common element in nature and can exist in the following forms in natural water and wastewater streams:

- Particulate phosphate: suspended inorganic phosphorus particles
- Orthophosphate (PO_4^{-}): inorganic phosphorus that may be present as H_3PO_4, $H_2PO_4^-$, HPO_4^{2-} or PO_4^{3-} depending on the pH. $H_2PO_4^-$ and HPO_4^{2-} are the most common in neutral waste water. Orthophosphates form complexes, chelates and insoluble salts with metal ions. It is highly recommended to remove as many orthophosphates from the RO/NF system as possible to prevent phosphate scaling.
- Polyphosphates: polyphosphates may contain 2 to 7 phosphorus atoms per molecule. Polyphosphates are common components in textile washing powders and other detergents.
- Organic phosphorus: the major form of total dissolved phosphorus, but can be present as dissolved or particulate organic phosphorus. It is an essential element for living organisms.
- Apatite: the most common mineral form of phosphorus. Apatite is a calcium phosphate with variable amounts of OH^-, Cl^-, and F^- (hydroxyl-, chloro- or fluorapatite). Some other phosphate minerals can contain aluminum and/or iron. Because of apatite's low solubility, a list of compounds are considered as causes of phosphate scaling (Table 1). Calcium phosphate and apatites are less soluble in neutral and alkaline conditions and dissolve in acid. Aluminum and iron phosphates, however are less soluble at moderately acidic conditions. This is another reason why it is highly recommended to remove aluminum and iron before the RO/NF system. To minimize the risk of phosphate scaling, it is also important to reduce calcium and fluoride.

TABLE 1. PHOSPHATE COMPOUNDS WITH LOW SOLUBILITIES (ARRANGED FROM MOST SOLUBLE TO LEAST SOLUBLE).

Compound Name	Compound Formula	pK_{sp}
Brushite	**$CaHPO_4 \cdot 2H_2O$**	6.7
Magnesium Ammonium Phosphate	$MgNH_4PO_4$	12.6
Iron Phosphate	$FePO_4$	15.0
Aluminum Phosphate	$AlPO_4$	20.0
Calcium Phosphate	$Ca_3(PO_4)_2$	28.9
Octacalcium Phosphate	$Ca_4H(PO_4)_3 \cdot 3H_2O$	46.9
Hydroxyapatite	$Ca_5(PO_4)_3OH$	57.7
Fluorapatite	$Ca_5(PO_4)_3F$	60.0

If high concentrations of phosphates exist in the feed and concentrate streams, the following pretreatment methods may help control scaling potential:

- The use of a scale inhibitor or antiscalant.
- Removal of aluminum, iron, calcium and fluoride to minimize the risk of phosphate scaling (please refer to the appropriate Pretreatment Guides for removal methods).
- Adjusting operational parameters including system recovery and incorporating a permeate flush.

PRETREATMENT

Scale Inhibitor or Antiscalant

A high quality scale inhibitor or antiscalant for phosphate scale may be helpful to use in the feed stream prior to the membrane system. For extremely high phosphate applications, the dosage rate may be predetermined by the chemical manufacturer.

MANN+HUMMEL Water & Fluid Solutions offers several antiscalants that battle phosphate species and helps protect and enhance the operation of RO and NF systems by controlling phosphate scale as well as other mineral scale. These antiscalants may significantly increase the allowable system recovery. For more information, please see product spec sheets at www.microdyn-nadir.com/trisep or contact MANN+HUMMEL Water & Fluid Solutions Technical Service.

OPERATIONAL CONSIDERATIONS

Recovery

The system's recovery may be lowered. At a lower operating recovery, the concentration of phosphate in the concentrate decreases and lowers scaling potential.

Permeate Flush

The membrane elements should be flushed for a minimum of 3 minutes with permeate water each time that the membrane system shuts down. This will flush out the highly concentrated water in the tail-end of the system which will prohibit precipitation during this stagnant flow period.

CLEANING PROCEDURE

A customized cleaning procedure may be implemented on a scheduled maintenance basis. This will ensure complete removal of any precipitated carbonate.

Please refer to MANN+HUMMEL Water & Fluid Solutions' **Membrane Cleaning Guide – Water Application Elements** (TSG-C-001) for cleaning recommendations using low pH cleaners TriClean™ 210 or TriClean™ 310 to battle phosphate.

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