

Colloidal fouling of RO membranes following MF/UF in the reclamation of municipal wastewater

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Abstract

Major municipal wastewater reclamation plants in California, USA, Singapore, and many built or planned for other regions of the world use the high pathogen reduction properties of microfiltration/ultrafiltration (MF/UF) membranes followed by reverse osmosis (RO) membranes. Operational experiences in these plants suggest that while MF and UF membranes encounter pore and cake fouling by colloidal particles (0.1 micron down to molecular sizes, ie. nanoparticles), a significant fraction of the smaller colloidal particles pass through the MF and UF membranes, and end up on RO membranes as cake-layer foulants. Autopsies, foulant analyses and cleaning studies performed on fouled RO membranes from the plants and pilot plants showed that colloidal natural organic matter, colloidal calcium phosphate and some times colloidal silicates are the main components. These colloidal particles have great affinity towards aggregation with each other. Due to incomplete removal by MF and even UF, fouling of RO membranes downstream becomes measurable by trend-charts of normalized values of permeate flow, differential pressure and salt passage. Normalized permeate flow is the most sensitive, and an early indicator of such fouling. In this paper we will provide some details of our studies and provide literature evidences that support the conclusion that calcium phosphate in foulants originated as nanoparticles in the wastewater.

Keywords: Municipal wastewater; Microfiltration; Ultrafiltration; Reverse osmosis; Colloidal fouling; Organic colloids; Colloidal calcium phosphate; Colloidal silica; Colloidal silicates; Nanoparticles

1. Introduction

The use of microfiltration (MF) or ultrafiltration (UF) as pretreatment to reverse osmosis (RO) membrane process offers the benefits of

additional high pathogen reduction credit as well as RO fouling mitigation for the treatment of secondary municipal wastewater. On this basis, major plants in California, USA, Singapore and Kuwait have been built and in operation with this design. Many major plants with this design will undoubtedly follow in China and elsewhere.

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Operating experiences in plants and pilot plants so far have shown [1] that colloidal fouling to varying degrees in both the first and second stages of ROs still occur despite MF or UF pretreatment. In the interest of fully controlling fouling of the RO membranes with antiscalants [2,3] and antifoulants [3], our efforts have been focused on differentiating between scaling and colloidal fouling [4] seen on the membranes [5,6], and developing methods for full control. While natural organic foulants and silica and silicates found on RO membranes can be presumed to arise from the coagulation and flocculation of colloidal organic and silicate particles that have passed through the MF/UF membranes upstream, the state in which calcium phosphate arrived in the RO system needs to be considered. If passage through the MF/UF pretreatment is in the form of dissolved calcium and orthophosphate ions, then deposition on the RO membrane would be by crystallization or scaling. Such a mechanism should be controllable by antiscalants. If passage through the MF/UF membrane is in the form of colloidal calcium phosphate particles, then antiscalants at low dosages would be relatively ineffective, requiring anticoagulant/dispersants [3].

Since we have found that antiscalants known to be very effective against calcium phosphate is relatively ineffective in controlling calcium phosphate deposition in the RO system, we have long suspected that calcium phosphate is passing through the MF/UF in the colloidal nanoparticulate [7] form, and coagulating with other colloidal particles in the MF/UF filtrate, giving rise to varying degrees of fouling in the RO system. Such depositions of calcium phosphate is easily cleaned by dissolving with acid cleaners. However, if calcium phosphate precipitates become extensively coated with organic foulants, RO membrane flux become increasingly difficult to recover by low pH and even very high pH cleaning. Report of similar fouling by calcium phosphate and organics in the full-scale plants in

UK and Spain [6], and Singapore [6,8] points to a general presence of colloidal (nanoparticles) of calcium phosphate in municipal wastewater around the world.

In this paper, we present the analysis of RO foulant from a severely fouled RO membrane, RO feedwater analysis from several municipal wastewaters relative to solubility product constant considerations for calcium phosphate and likelihood of presence of calcium phosphate in the colloidal form supported by the literature.

2. Early encounter

Since 1975 until the recent shutdown for plant reconstruction, Water Factory 21 in Orange County, CA, had famously treated 15 million gallons per day (mgd) of secondary municipal wastewater using lime-softening followed by RO.

Table 1
Composition of RO foulant resulting from MF pretreatment

Gravimetric assays (absolute % by weight):	
Carbon	6.83
Hydrogen	1.87
Nitrogen	0.64
Ash	80.47
Scanning electron microscope–energy dispersive X-ray (relative weight % excluding carbon, oxygen and nitrogen):	
Calcium	53
Phosphorous	33
Magnesium	3.6
Iron	2.6
Sulfur	2.0
Sodium	2.0
Silicon	1.1
Chloride	0.7
Manganese	0.6
Aluminum	0.6
Potassium	0.2

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