ELSEVIER

Desalination 172 (2005) 1–6

DESALINATION

www.elsevier.com/locate/desal

Chemical control of colloidal fouling of reverse osmosis systems

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Received 12 September 2003; accepted 21 June 2004

Abstract

Fouling of membranes by colloidal organic and inorganic particles continues to be documented as the most common and challenging obstacle in attaining stable continuous operation of reverse osmosis (RO) and ultrafiltration (UF) systems. Much current research is being conducted on physical parameters to mitigate such fouling. The focus has been on membrane synthesis and element design; microfiltration and ultrafiltration pretreatment; electromagnetic devices; correlation with physical factors such as Silt Density Index, zeta potential and critical flux; technique of direct observation of fouling process through a membrane; and classification of macromolecular organics for correlation with fouling characteristics. We report initial successes with chemical control of colloidal fouling. Through screening with a large number of observable coagulations of natural colloids, we have developed a group of proprietary anticoagulants and dispersants that would, at less than 10 ppm dosage to the RO feedwater, control various classes of colloidal foulants. Case studies of the control of humic matter, elemental sulfur and colloidal silicate in problematic RO systems that became stabilized are briefly presented. We conclude that a great need and potential exists in economically controlling the myriads of fouling interactions of colloidal particles during concentration within the brine channels of RO membrane elements. Low dosages of antifoulants can in many cases obviate the need for installation and maintenance of pretreatment unit or operations designed to remove such colloidal foulants from the process stream.

Keywords: Colloidal fouling; Colloids; Ultrafiltration; Reverse osmosis; Membrane fouling; Humic matter; Elemental sulfur; Colloidal silica; Anti-coagulant; Dispersant; Antifoulant

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Presented at the World Congress on Desalination and Water Reuse, International Desalination Association, 28 September–3 October 2003, the Bahamas.

doi:10.1016/j.desal.2004.06.192

1. Introduction

Fouling of membranes by colloidal organic and inorganic particles continues to be documented as the most common and challenging obstacle in attaining stable continuous operation of reverse osmosis (RO) [1–9] and ultrafiltration (UF) [10–13] systems. Much current research is being conducted on physical parameters to mitigate such fouling. The focus has been on membrane synthesis and element design [14,15]; microfiltration and UF pretreatment [16,17]; electromagnetic devices [18–20]; correlation with physical factors such as Silt Density Index (SDI) [21–24], zeta potential [25, 26], and critical flux using a technique of direct observation of the fouling process through a membrane [27–29]; and classification of macromolecular organics for correlation with fouling characteristics [30–33]. We report the initial successes with chemical control of colloidal fouling.

2. Chemical approach

Colloids that can affect the operation of membrane systems are finely dispersed solid particles or liquid droplets that escape filtration by sand, multimedia and 5 or 1 micron guard filters. They range in size from 0.1 to 0.005 microns, just above molecular dimensions, exhibiting physicochemical properties that differ from those of both the constituent molecules and the macroscopic material. Colloids have high surface-area-to-volume ratios giving them singular, diverse and often curious properties [34]. They generally coagulate at increased concentration and salinity as found in the processing conditions of membrane systems. A vast body of literature documents the complexity of colloidal interactions and changes in properties by surface modifications of particles through adsorption or reaction with ions, molecules or other particles.

Through screening of a large number of observable coagulations of natural colloids that are present in surface waters, we have developed a group of proprietary anticoagulants and dispersants that would, at less than 10 ppm dosage to the RO feedwater, control various classes of colloidal foulants. We present brief case studies of the control of humic matter, elemental sulfur and colloidal silicate in problematic RO systems that became stabilized.

3. Case study on humic matter

A large paper pulp facility on Lake Superior, Canada, draws water from a bay with floating logs and much humic matter from decaying wood. It has three RO trains, each designed to be fed at 400 gallons per minute (gpm) (91 m^3/h), producing 300 gpm (68 m^3/h) each of permeate to provide boiler feedwater and water for manufacturing processes. Each train is in an 8:4 array of six-element vessels with a total of 72 8" membrane elements. The raw lake water is chlorinated, filtered through a multimedia filter (MMF), dechlorinated with bisulfite, and treated with 2–6 ppm of antiscalant, and passed through 5-micron cartridge filters before the RO trains. The SDI of the raw water varies with the season, averaging about 13.0. Dissolved iron concentration was about 0.03 ppm.

When started up in May, 1999, the 5-micron filter cartridges lasted for 3 days, and for the following year required changing every 3–7 days, despite the upgrading of the MMF packing and introduction of air-scouring. Fouling of the membranes was severe, requiring cleaning every 5 days on average. Over the first year, membrane flux loss was severe. The differential pressure (ΔP) of the first stages of all three trains increased to about 150 psi (10.5 kg/cm^2), crushing about 30 membrane elements that had to be replaced. System down-time and cleaning chemical supply to this relatively remote plant site became a problem.

At this point a full investigation was conducted and a monitoring for process improvement