Journal of Environmental Chemical Engineering 1 (2013) 33–37

Contents lists available at SciVerse ScienceDirect

Journal of Environmental Chemical Engineering

journal homepage: www.elsevier.com/locate/jece

Predicting colloidal fouling of tap water by silt density index (SDI): Pore blocking in a membrane process

Muddasar Habib [a,*], Unsia Habib [a], Abdul Rehman Memon [b], Usman Amin [c], Zahid Karim [a], Amad Ullah Khan [a], Sayed Naveed [a], Sultan Ali [a]

[a] Department of Chemical Engineering, University of Engineering and Technology, Peshawar 25120, Pakistan
[b] Department of Chemical Engineering, Mehran University of Engineering and Technology, Jamshoro, Pakistan
[c] Institute of Medical Sciences, Khyber Medical University, Kohat, Pakistan

ARTICLE INFO

Article history:
Received 4 February 2013
Accepted 13 March 2013

Keywords:
Colloidal fouling
SDI index
RO membrane
Pore size

ABSTRACT

Colloidal fouling of reverse osmosis (RO) elements can seriously impair the performance of membranes resulting in loss of productivity. The source of silt in water is varied and often includes bacteria, clay, colloidal silica, and corrosion products. Various pre-treatment chemical can be used to agglomerate the fine colloidal particles which in-tern can be removed easily however if the incorporation of pre-treatment chemicals with the fine colloidal particles fails then these pre-treatment chemicals can also become a source of membrane fouling. In addition, cationic polymers may co-precipitate with the negatively charged anti-scalants resulting in membrane fouling. Several methods have been proposed to predict the colloidal fouling potential of feed water such as the modified fouling index (MFI) and the most commonly used silt density index (SDI). SDI is an important design parameter for an RO membrane water treatment process. In this investigation the effect of SDI index was investigated to predict the fouling tendency of different pore size membranes. The SDI index showed elevated values (~12) with big pore size (2, 3, 5, 10 μm) membranes however lower fouling index values (~6) were recorded with membrane pore sizes near to 0.45 μm even with different kind and make of membranes.

Introduction

The demand for high quality portable water is on the rise as the availability of adequate drinking water resources are increasing becoming scare. Recent years have seen the membrane processes to emerge as a viable technology for water and wastewater treatment which can provide superior quality water with low energy consumption. The environmental friendliness of a membrane process is evident from the fact that they do not require the use of hazardous chemicals in the production process in comparison with other conventional water reclamation technologies [1,2]. A membrane is a thin sheet of natural and/or synthetic material that is permeable to certain substances in a solution. Various types of membranes exist but the use of semi-permeable reverse osmosis (RO) membrane is of particular interest in advanced wastewater reclamations, however, the presence of fine particulate matter (originating from organic and inorganic compounds, suspended solids, and microorganisms) remains a problematic issue which contribute to RO membrane surface fouling [3]. Four main membrane fouling mechanisms are proposed: (1) biofouling, (2) particulate fouling (3) organic fouling and (4) scaling [4]. This work has looked into colloidal fouling of different membranes.

Membrane fouling arises from specific interactions between the membrane and foulants in raw water which makes the membrane processes less efficient and reduces their economic advantages, e.g., due to frequent chemical cleaning of membrane element and as a result its increased subsequent replacement frequency [4–14]. Deposition and accumulation of foulants such as micron sized colloidal particulates on the membrane surface not only result in permeate flux to decline but also deteriorates the permeate quality [15,16]. Membrane fouling is affected by operating conditions such as the flux, recovery, and cross flow rate [4,5,17–20] however a more fundamental cause of membrane fouling is the presence of colloidal particles in feed water [21–24]. Understanding the cause of membrane fouling and developing strategies for fouling control are of paramount importance for the successful application of membrane technology for RO water treatment [3,25,26,39]. Hence there is pressing need to devise a reliable method to measure and predict the fouling potential of feed water so that it can be used at

* Corresponding author. Tel.: +92 91 9218180; fax: +92 91 9218180.
E-mail address: muddasar77@hotmail.com (M. Habib).

2213-3437/$ – see front matter © 2013 Elsevier Ltd All rights reserved.
http://dx.doi.org/10.1016/j.jece.2013.03.005

design stage to assess the required pre-treatment and at later stage to evaluate the effectiveness and performance of the selected pre-treatment system.

Silt density index (SDI) test (whose standard protocol is covered by ASTM ASTM D 4189-95, reapproved 2002) is particularly developed from decades to predict the rate of colloidal and particulate (<0.45 μm) fouling in RO membranes [4,3,28,29] including fouling resulting from the presence of soluble organic matter [30]. SDI test and its modified forms are more recently used to predict the performance of micro- and nano-and ultra-membrane based water treatment systems [4–7,25,26] (Alhadidi et al., 2013). SDI test acts like a guide for pre-treatment which estimates the rate at which the particle and colloidal fouling will occur and is not necessarily an indication of any appropriate pre-treatment. SDI is determined from simple membrane experiments. The reported general fouling index range for RO process is SDI = 0–2 [31]. It has been reported that this value can be used to determine the pre-treatment requirements without conducting a pilot study, which needs considerable time and expenses [31]. However the SDI fouling index value is a standardized parameter (measured with a 0.45 μm pore membrane) and often fails to reflect the true fouling strength of actual feed water [24,32,33]. Even the proposed modified fouling index (MFI) fails to predict the true fouling potential [34]. There are growing doubts about the reproducibility, applicability and accuracy of SDI test which may be due to the nonexistence of a linear relationship with the concentration of colloidal/suspended matter, due to the empirical nature of the test which is not based on any filtration mechanism and not corrected to any temperature, pressure, air entrainment, operator inaccuracies, <0.45 μm pore sizes and membrane property such as permeability [4–7]. To overcome these deficiencies MFI has been developed however its measurement is more complicated than SDI and hence it is useful to look for improvements in the existing SDI test [4].

Although membrane industry is widely using the SDI test as a design and operational parameter for RO, the meaning of test on physical basis and the correlation of calculated plugging factors (such as surface porosity, material of construction, hydrophobicity, molecular cut off, pore size, feed water composition, ionic strength, pH, cross flow velocity, permeate flux and temperature) with the tendency of membrane surface to foul (with corresponding performance loss) are not well understood [4–7,22,23,35–37]. Hence it is very critical to fundamentally understand the variations of existing fouling indices under various feed water and membrane characteristics. This is the main objective of this reported investigation which was aimed to provide valuable information on the utilization of existing SDI fouling index test to predict the fouling potential of different and varying pore size membranes.

Table 1
Investigated membrane types and their corresponding pore sizes.

	Membrane type	Pore Size	Supplier
1	Versapor polyacrylonitrile	0.45 ± 0.2 μm	Millipore
2	Isoporemembrane	0.4, 0.8, 2, 3, 5, and 10 μm	Millipore

Materials and methods

SDI tests were performed by timing the anaerobic hydraulic flow through a 47 mm (13.8 × 10^{-4} m^2) diameter, with an average 0.45 μm pore size, membrane (Millipore Crop) filter at constant pressure (30 ± 1 psi ≈ 2 atm) and temperature (±1 °C) by following the ASTM D 4189-95 standard. Operating flow diagram of the SDI test and the actual apparatus setup is shown in Fig. 1.

The apparatus used in this work (Fig. 1) consisted of membrane filters whose characteristics are reported in Table 1, a pressurized feed reservoir (stainless steel construction to prevent any contamination) suitable to work at 30 psi (~2 atm) with the provision for pressurized water inlet and outlet, a 47 mm filter holder (stainless steel construction) capable of operating at the required pressure (30 psi ≈ 2 atm), weighing unit, pressure gauge, measuring cylinder, and computer for data logging of time and permeate mass.

Before installing the membrane filter, deionized RO water was flushed through the apparatus to remove any entrained contaminants. Temperature of the feed water was then recorded and the feed holder was opened to place the adequately sized (47 mm diameter) and wetted (with deionized RO water to avoid puncturing by the initial high pressure flow) membrane filter on the support plate. The silicon O-rings were then properly placed before the filter holder was fully closed. Care was taken to remove any entrained air before and after the closure.

To run the test the ball valve was opened with simultaneous recording of permeates mass and the elapsed time by means of a data logging computer. First non-plugging reference water (obtained by deionizing and passing through a 0.2 μm pore size RO) was used to record the time "t_i". This time was used for comparison with the actual SDI tests to look for any inconsistent

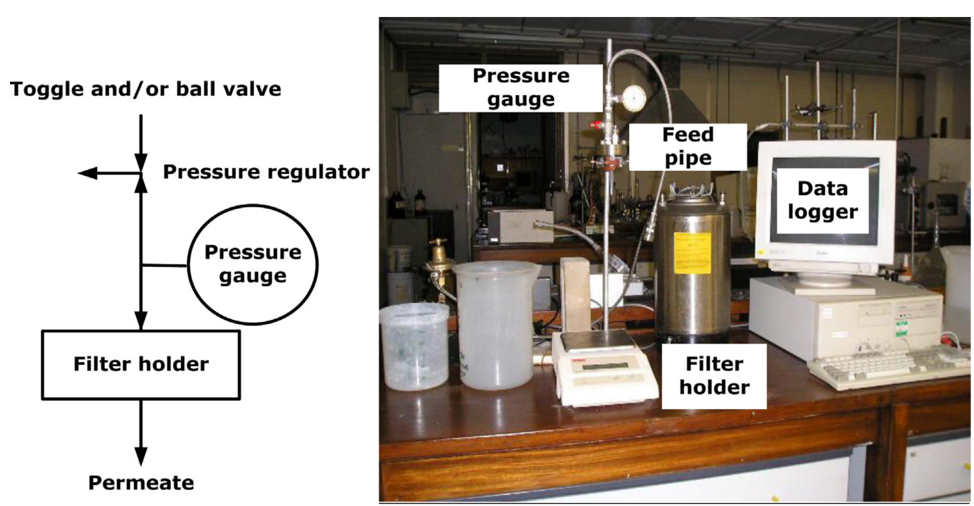

Fig. 1. Experimental setup for SDI measurements.