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Backwash of RO spiral wound membranes

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Abstract

Osmotic backwash experiments were conducted and analytical model was developed in attempt to describe the backwash mechanism. A single unit of a spiral wound RO membrane was used in the experiments. The RO membrane was fed by salted water solution. Permeate flux characteristics of the membrane were determined through steady-state RO experiments. Then the system was shifted immediately to a backwash process by reducing the feed pressure, Δp, either to zero or to a level below the osmotic pressure to allow net backwash driving force. The backwash experiments reveal that the backwash process has two distinct regions. The flow rate drops sharply at the initial backwash process, followed by a prominently slower flow rate continuously slows down until it reaches a constant value (toward zero, for $\Delta p = 0$). These results suggest that the first backwash stage acts mainly to dilute the salt concentration at the feed concentration polarization (CP) layer. The second stage of the backwash flow rate exhibits salt dilution of the bulk solution. RO experiments were conducted also with a super-saturated $CaCO_3$ solution, to cause salt precipitation and partially clogging of the membrane surface followed by flux reduction. The permeate flux was resumed to its original level with osmotic backwash cleaning of the membrane. Effects of three independent RO feed variables; feed concentration, flow rate, and applied pressure, on the accumulated volume of backwash water, $v(t)$ were analyzed experimentally. It was found that feed concentration has the strongest effect on $v(t)$, while the other two parameters has only minor effects on the process. Presence of operational pressure during the backwash process reduces $v(t)$ dramatically, as a consequence of the driving force reduction. A simple analytical model was developed and fits well the experimental data of the second stage without feed flow during the backwash process.

Keywords: Desalination; Backwash; Cleaning; Reverse osmosis; Osmotic backwash

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1. Introduction

Fouling is an inherent phenomenon in RO desalination technique. It may build up on the membrane surface progressively during the desalination process and thereby deteriorates the membrane performance [1–3]. Furthermore, some fouling types, such as biofouling, scaling of silica and others, when detected in an advanced stage may be irremovable [1], causing irreversible damage to the membrane. In the present study it was clearly shown that dissolving of $CaCO_3$ salt from the membranes by osmotic backwash can easily be made immediately after precipitation. As time goes on, the dissolution of the salt may be impossible due to hardening of the scale. To minimize RO plants deterioration due to fouling, periodic cleaning of the membrane is essential. The selection of a cleaning method depends on the type of the foulant.

There are three main cleaning methods: physical, chemical, and physicochemical methods [4]. Chemical cleaning methods are assigned to weaken cohesion forces between the foulant and the membrane surface [3]. The chemical methods are useful in biofouling and scaling of silica [1]. UF membranes, in filtration of wastewater, are cleaned with liquids or gases containing chemical agents [5–7]. Some membranes are vibrated by feeding of gases to accelerate pollutants separation from the membrane surface, in addition to chemical agents [8].

Physical cleaning methods include forward and reverse flushing, backwashing, vibrations, air sparging and CO_2 back permeation. Of the physical methods, the backwash method has proved to be an efficient physical cleaning method for flux recovery of membranes not severely fouled [3]. The backwash used in membranes is based on permeate back-flow to the concentrate side [9–11]. Therefore, membranes must have high pressure durability in both directions, which is not the case for RO spiral-wound membranes. An osmotic cleaning of RO membranes is based on flow induced by osmotic pressure as direct osmosis cleaning (DOC) [12]. The cleaning process in DOC is based on negative driving pressure between the operating and the osmotic pressures of the water solution in the feed side of the membrane. This can be done either by reducing operation pressure below the osmotic pressure of the solution or by increasing the permeate pressure to a level that allows backflow. The later possibility is carried out without changing parameters of the feed side of the RO process, yet high pressure piping is required at the permeate side.

Minimizing the backwash time and the amount of water needed are major purposes of the backwash process, as it saves permeate water and production time. The minimization can be done by determining the minimum amount of permeate water necessary to remove the contamination accumulated on the membrane, which is out of the scope of this work.

As a preliminary study, the main purpose is to investigate the backwash mechanism and identifying its main parameters. The present study contains detailed definition of the backwash problem for a single spiral wound membrane, in which the driving force of the backwash water is the osmotic pressure alone, i.e. atmospheric pressures allows on both the permeate and the concentrate sides. A mathematical model was developed and verified by corresponding experiments. Additional experiments were conducted for backwash pressure under lower pressure drops, bellow the osmotic pressure.

2. Theory

The present mathematical model together with experimental data were assigned to point at two backwash stages comprise the backwash mechanism. The experimental situation underlined the present model is as follows: The backwash process starts as soon as the RO stops. Physically, the start moment of the backwash process is when the net applied pressure drops below the osmotic pressure, $\Delta\pi$. This is the moment at which the permeate