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# [OD38] Influence of feed spacer geometries on air/water cleaning in spiral wound membrane elements

Y. Wibisono*[1,2], E.R. Cornelissen[3], A.J.B. Kemperman[2], D.C. Nijmeijer[2], W.G.J. van der Meer[4]
*[1]Wetsus, The Netherlands, [2]University of Twente, The Netherlands, [3]KWR Watercycle Research Institute, The Netherlands, [4]Delft University of Technology, The Netherlands*

High-pressure membrane processes, i.e. reverse osmosis (RO) and nanofiltration (NF), are increasingly used in drinking water treatment, seawater desalination, wastewater reclamation and for the production of water for industrial purposes. However, the key problem in spiral wound membrane processes is the occurrence of biofouling and particulate fouling which results in a high pressure drop and an uneven distribution of flow within the membrane element. This causes operational problems, such as production loss, and potentially a deterioration of the product water quality. To control this problem, a periodical membrane cleaning is required which leads to an increase in the use of cleaning chemicals. Vrouwenvelder et al. (2009) reported that the feed channel pressure drop (FCP) increase in spiral wound membrane elements caused by biomass accumulation was not affected by both permeate flux or membrane type. Their study showed that biofouling is predominantly a spacer related problem, and feed spacer adaptation (coated/modified geometry) to enhance channel cleanability was proposed. Parallel to this research, the new and innovative 'AiRO' process has been introduced by KWR Watercycle Research Institute, in which air/water cleaning is periodically carried out in vertically positioned, spiral-wound membrane elements (Figure 1). It has been shown that air/water cleaning can effectively remove biofilm and particulate matter from fouled spiral-wound membrane elements, and therefore this technology is an effective cleaning strategy (Cornelissen et al., 2010a). Considering the benefits demonstrated in previous studies, this work investigates the effect of feed spacer geometries, i.e. shape and thickness, on the efficiency of fouling removal by air/water cleaning in spacer-filled membrane channels.

A high-speed camera system (up to 285 frames per second) monitors the air/water cleaning process using model foulants, and is used to study (i) the fouling mechanisms such as entrapment of particles onto the spacer material and/or membrane surface and (ii) the behaviour of a two-phase system (air and water) in the spacer-filled channel. Sodium acetate dosing in the tap water is used to promote biofouling, and modified polystyrene particles were used as model particles foulants. The air and water flows are controlled by mass flow controllers, and a differential pressure sensor measures the FCP increase of the flow cell. All data are logged simultaneously on a computer. The flow cell has been made from 1 cm thick PMMA plates. The bottom plate is tapered to a spacer-filled channel of 20 mm x 170 mm and to define channel gaps of 0.5/0.7/1.2 mm thicknesses. Mixtures of air/water inlet were used in the experiment mimicking the actual use in the pilot plant. A total of five diamond-type spacers were selected, corresponding to three different channel gaps to provide compact and close-fitting arrangement of the spacer-filled channel. These types of spacers were most commonly used by spiral wound manufacturers. The geometric characteristics of the spacers investigated are given in Table 1. Despite permeation does not influence the effectiveness of air/water cleaning in spiral-wound element (Cornelissen et al., 2010b), a flat sheet type NF membrane (Hydranautics ESNA1-LF2-LD) was used to enhance fouling development in the channel. The images and movies collected from experiment were analyzed by image processing software to determine the bubble size and distribution for the different spacer geometries and relate this to the air/water cleaning efficiency.




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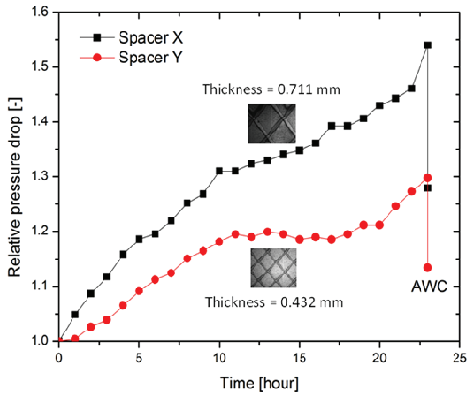
**Figure 1.** The principle of air/water cleaning in spacer filled membrane channels to control biofouling and particulate fouling.

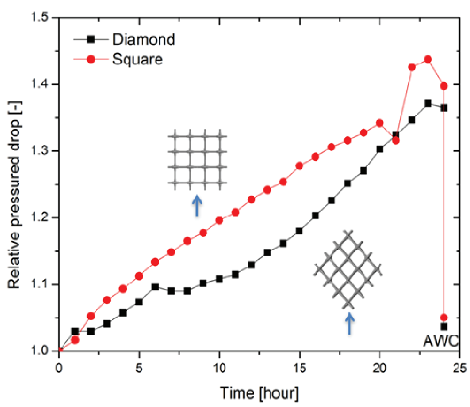
**Table 1.** Overview of narrow channel and feed-spacer geometries.

| **Channel gap** | **Spacer Geometries** | | | **Standard Polymer** |
|---|---|---|---|---|
| | **Average Thickness** | **Shape** | **Filament Angle** | |
| **0.5 mm** | 0.508 mm | Diamond | $90^o$ | PP |
| | 0.508 mm | Diamond | $60^o$ | PBT |
| **0.7 mm** | 0.800 mm | Diamond | $90^o$ | n.a. |
| | 0.650 mm | Diamond | $90^o$ | PP |
| **1.2 mm** | 1.168 mm | Diamond | $90^o$ | PP |

The effectiveness of air/water cleaning is determined as a function of: i) particle characteristics; ii) spacer geometry; iii) bubble size and shape; iv) bubble distribution; v) volume ratio of air and liquid phases; and vi) air/water superficial velocities. Two-phase flows conditions in the spacer-filled channel are evaluated by geometrical parameters of the spacers and the channel flow cell, i.e.: hydraulic diameter, porosity etc., based on the methods described by Schock and Miquel (1987). Figure 2a shows the preliminary results of 5 $mgL^{-1}$ polystyrene particles solution fed to a spacer filled channel at a linear feed velocity of 0.09 $ms^{-1}$. Feed channel pressure drop and air/water cleaning behave differently when using different feed spacer sizes at a constant channel thickness. Feed channel pressure drop also depends on the spacer orientation in the channel (Figure 2b), however air/water cleaning performance remains similar. Figure 3 shows snapshots of real time observations of air/water cleaning in the spacer-filled channel.




(a)



(b)

**Figure 2.** FCP increase and air/water cleaning in the narrow channel (0.7 mm)

in different feed-spacer thickness (a) and orientation (b).

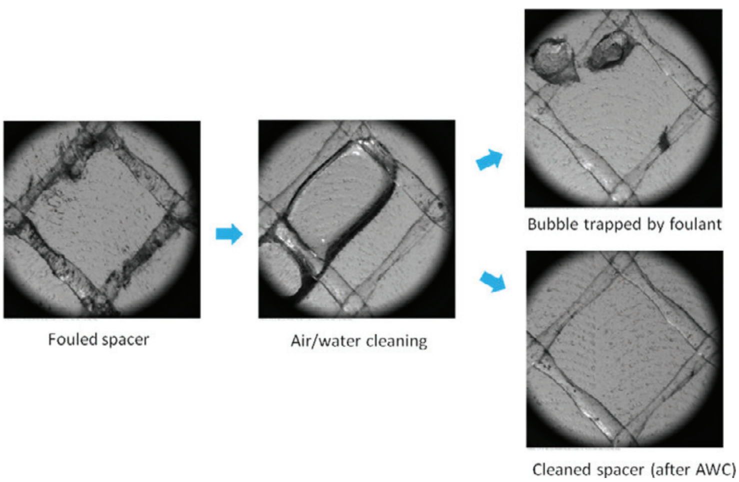



**Figure 3.** Bubble behaves during air/water cleaning in spacer-filled channel.

It was concluded that air/water cleaning is effective to remove fouling for different fouling types, air/water velocities, and spacer geometry. Furthermore, spacer geometry influences the local velocity, fouling behaviour and air/water cleaning efficiency. Spacer orientation affects the hydrodynamic behaviour inside the feed channel and increased the FCP, however at the same channel voidage or porosity ($\varepsilon$), the effect of air/water cleaning remains similar.

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