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Periodic electrolysis technique for *in situ* fouling control and removal with low-pressure membrane filtration

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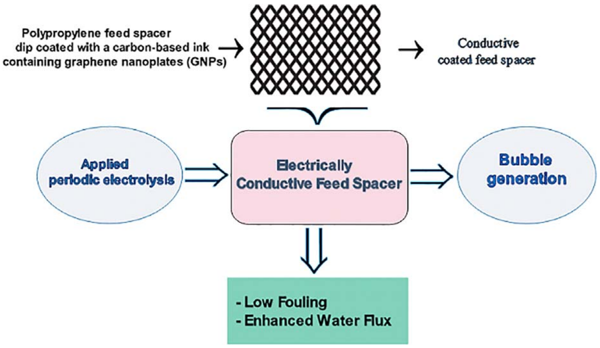
GRAPHICAL ABSTRACT



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ABSTRACT

Electrically conductive membranes and their application for desalination pre-treatment and water purification have an exceptional performance due to self-cleaning of fouling deposits by the application of external electric fields. However, the effectiveness of existing conductive membranes is hampered by their common applications. The current approach aims to better understand the *in situ* fouling mitigation and enhanced flux by employing two different electrically conductive coated feed spacer configurations during filtration of humic acid at concentrations of 8, 12, 16 and 20 ppm. Periodic electrolysis was applied for a duration of 2 min with three intervals of 30, 45 and 60 min. A comparison of both the feed spacers was made in terms of the effect of the applied potential and interval time on enhancement of water flux, as well as the required energy consumption at four different concentrations. In terms of enhanced flux and energy consumption, feed spacer A (2 × 2 mm aperture size) revealed better results than feed spacer B (3 × 2 mm), which may be attributed to a greater conductive area. The reported technique shows a major advantage of *in situ* feed spacer self-cleaning, thus providing a continuous and non-destructive approach for the mitigation of surface fouling.

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1. Introduction

Microfiltration is a low-pressure membrane process, which is increasingly being employed as an alternative to conventional clarification processes for the removal of microorganisms, turbidity and natural organic matter (NOM) in the water treatment process. In some situations, the microfiltration membranes are applied to obtain the ultimate treatment, while sometimes they are used as a pre-treatment for downstream advanced water treatment processes, such as reverse osmosis [1–11]. In pressure-driven membrane processes, membrane fouling is a ubiquitous phenomenon and considered to be a major problem leading to decreased flux, potentially to below the theoretical membrane capacity without appropriate treatment [8, 12–16].

Fouling is the adsorption of solute and particulates at the membrane surface or within the pores of the membrane. Mechanisms including the plugging of membrane pores, concentration polarization and cake layer formation at the membrane surface contribute to fouling build up on or within the membrane. Fouling deposits increase the required transmembrane pressure and necessitate use of chemical cleaning agents, which reduce membrane lifetime and increase operating costs [3, 17–26]. Although the fouling term can be related to both reversible and irreversible foulant adsorption, irreversible is the most problematic as it produces a flux decline that cannot be totally recovered [8, 27–31].

NOM is responsible for organic fouling and flux decline during microfiltration [32, 33]. The flux decline during water filtration results from increased resistance in the filtration system [34]. This is due to the permeability of the gel layer (surface cake) generated by colloidal material accumulation at the membrane surface, and/or to the membrane pore size reduction [18, 35–38]. Humic substances are typically classified into three categories: fulvic acids, humic acids (HA) and humin according to their solubility in water at different pH values [38, 39]. HA is an essential component of NOM and is a degradation product of biological molecules including carbohydrates, lignin, and proteins. It is commonly found in soils, and ground and surface waters in amounts varying with the seasons. It imparts a yellowish-brownish colour, as well leading to membrane fouling problems in water filtration processes [40–43]. It is a heterogeneous of both aliphatic and, aromatic components comprising three major functional groups: carboxylic acids (COOH), phenolic alcohol (OH), and methoxy carbonyl (C=O). Generally, it is more hydrophobic than other humic material. Fig. 1 shows a model structure for HA [44].

Nanofiltration and reverse osmosis processes have been broadly used to remove humic substances, since they have many advantages, such as small footprint area, high product quality, and lowered chemical reagent use. However, these membranes operate at high-pressure, which leads to high water costs [17, 45–50], as humic substance adsorption at the membrane surface results in increased hydraulic pressure requirements and operating efficiency losses. Therefore, pre-removal of humic substances using low-pressure membranes is an active area of research [50, 51].

Fouling models for microfiltration are used to determine the optimal set of operating conditions that minimize fouling and the frequency of backwashing and/or chemical cleaning required [31]. Previous investigations have sought to remove HA from feed water, assuming that HA is the major foulant type [29]. Yuan et al. [38] investigated filtration of 2 mg/L HA solutions through a 0.22 μm poly(vinylidene fluoride) (PVDF) microfiltration membrane for durations of 1, 5, 20 and 100 min. The initial filtration value for the membrane was

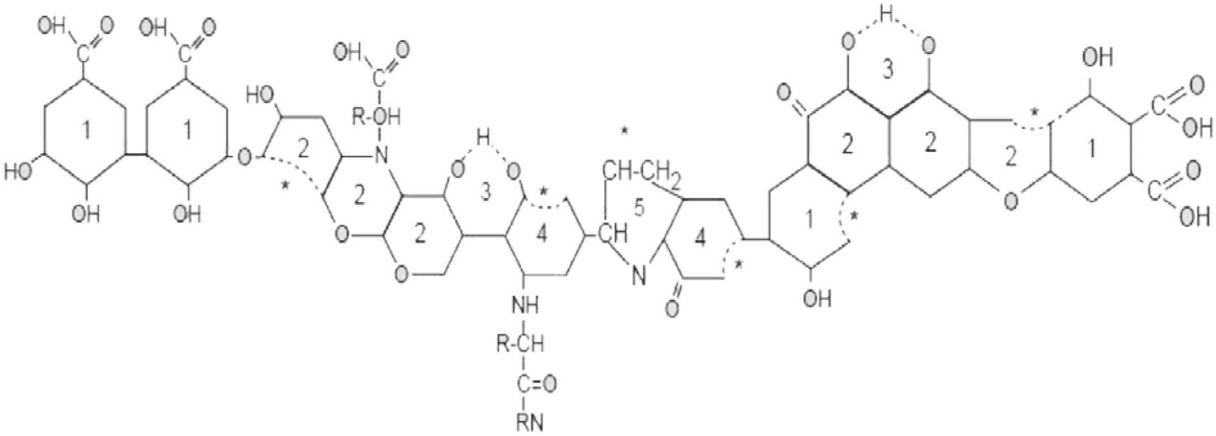

Fig. 1. Model structure of humic acid [44].

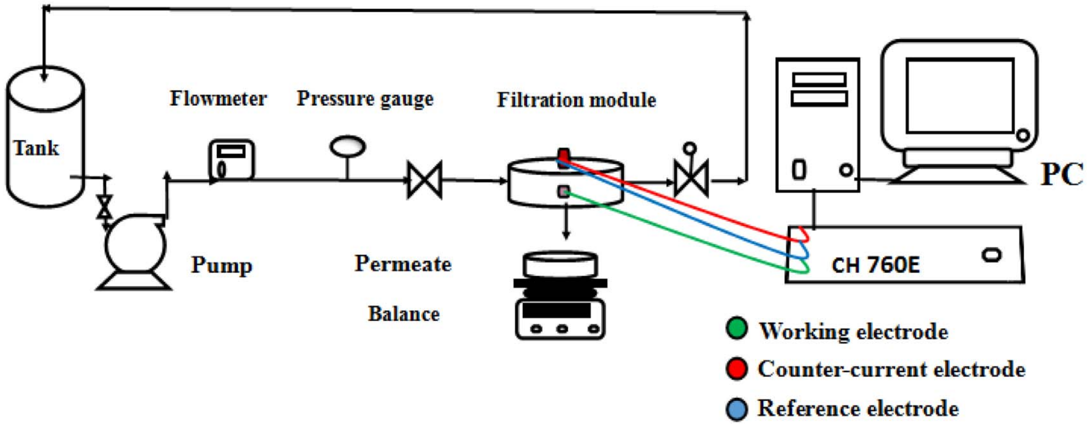

Fig. 2. Schematic representation of the enhanced cross-flow set-up.