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Influence of pre-treatment combinations on RO membrane fouling

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HIGHLIGHTS

- Different combinations of pretreatment for RO used in remote area were assessed to reduce organic fouling.
- Two types of waste water were used in the experiments.
- TOC reduction was assessed for each barrier and pretreatment combination.
- The RO performance was assessed based on flux decline till the overall recovery about 70%.
- Ozone + Ceramic membrane + BAC in all combinations gave a best protect to RO membrane.

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ABSTRACT

Pretreatment before reverse osmosis systems in water reuse plants is necessary to prevent rapid fouling. The secondary effluent can at times contain a high suspended solids load with a high proportion of colloidal material, organic compounds and bacteria. Such constituents can cause irreversible fouling of downstream RO systems if not successfully removed during pretreatment. To minimise RO membrane organic fouling, a pretreatment combination including advanced oxidation (ozonation), ceramic MF and biological activated carbon (BAC) was assessed. It was found that fouling formed by the feed wastewater pretreated by the combination of ozonation + ceramic MF and BAC can be easily removed by deionised water flushing, in comparison with MF, BAC, or ozone + MF.

1. Introduction

It was predicted that in the 21st century, a quarter of the world's population or a third of the population in developing countries will live in regions that will experience severe water scarcity [1]. Several measures to alleviate stresses on water supply should be implemented, including water conservation and updating water supply systems [2]. However, the only methods to increase water supply beyond what is available from the hydrological cycle are desalination and water reuse [3].

Many large-scale seawater desalination plants have been built worldwide, and most are located in the Middle East [4]. However, for small communities in remote arid inland locations, small water reuse plants are becoming a more widely accepted option for provision of safe and sustainable fresh. For the production of freshwater from wastewater effluent, reverse osmosis (RO) has gained wide acceptance, since it is able to effectively remove chemicals of concern (CoCs) and pathogens [5], as well as salt.

RO membranes purify water by size exclusion, charge exclusion and physico-chemical interactions between solute, solvent and membrane [6,7]. However, membrane fouling, caused by adsorption of solutes on the membrane surface [8] and filter cake build up, is a significant limiting factor for RO membrane application in water reuse [5,9]. To maintain membrane performance and clean fouled membranes, skilled expertise and chemicals are required. The authors have considered the application of small scale water recycling for remote areas such as Antarctica [10,11], and such considerations have identified that accessibility and storage of chemicals are limited, and the cost of a dedicated operator is expensive in such locations, although remote operation with local maintenance of the plant is realisable. Therefore, whether the RO membrane can be well protected by pretreatment is a significant determinant for employing water reuse plants in remote areas. Furthermore, in most remote areas, the environment is often fragile, and

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minimising the environmental impacts of sewage effluent discharge and the introduction of chemicals and disinfection by-products should be critically controlled.

Currently, RO feed pretreatment is mainly used to reduce suspended and colloidal material in the feedwater [12]. Conventional pretreatment includes disinfection, flocculation/coagulation and filtration processes, including microfiltration or ultrafiltration [12].

In reuse plants, the feed water to the pretreatment system is most commonly secondary sewage (biologically treated municipal wastewater). The quality of secondary effluent can be variable, and at times may contain a high suspended solids load with a high proportion of colloidal material, organic compounds and bacteria. These constituents can cause irreversible failure to the downstream RO system if not successfully removed during pretreatment [9]. Currently, continuous polymeric microfiltration or ultrafiltration (UF) is the most popular pretreatment technology [9]. However, polymeric membranes also need chemical cleaning and can be damaged by contact with oxidants. Furthermore, dissolved organic carbon (DOC), identified as the dominant foulant in most RO membrane plants [13], cannot be removed effectively by MF and UF. Indeed, due to incomplete feedwater pretreatment, even a rather small concentration (i.e. a few ppm) of commonly present organic macromolecules can cause significant membrane fouling [13]. Furthermore, fibre breakage of polymeric hollow fibre MF and UF requires skilled operators for pinning to maintain integrity.

Ceramic MF membrane is an emerging low-pressure membrane technology, and can be operated fully automatically [14]. Compared to polymeric membranes, ceramic membranes have higher oxidation resistance, can bear much higher backwash pressure [15], and do not experience fibre breakage. Furthermore, the irreversible fouling potential of ceramic membranes is less than that for polymeric membranes [16]. With the assistance of ozonation, it has been speculated that ceramic membrane shows a catalytic effect, which boosts oxidation [17] and reduces fouling. Compared to polymeric membranes, these features of ceramic membranes make them attractive for remote area deployment due to robustness to chemical cleaning [15], no fibre breakages and lower maintenance [18].

To find a way to minimise RO membrane organic fouling, a pretreatment combination including advanced oxidation (ozonation), ceramic MF, and BAC was proposed. The aims of the combination were to increase the content of biodegradable organics by ozonation [19], reduce fouling of the ceramic MF while allowing effective particle removal, and stabilisation of the water through removal of biodegradable organics by BAC. Ozonation and BAC were also expected to remove trace organic compounds (TrOCs) that would otherwise be rejected by the RO membrane and discharged to the environment. Ozonation, ozonation-ceramic MF and BAC alone were compared with the proposed pretreatment of ozonation-ceramic MF-BAC, based on the fouling performance of RO membrane and surface morphology after simple deionised (DI) water cleaning of the RO membrane. This cleaning regime was proposed for a water recycling plant of similar configuration that was tested in preparation for deployment to Antarctica. The plant was designed to operate intermittently with a permeate flush of the RO membranes each time the plant regularly ceased operation.

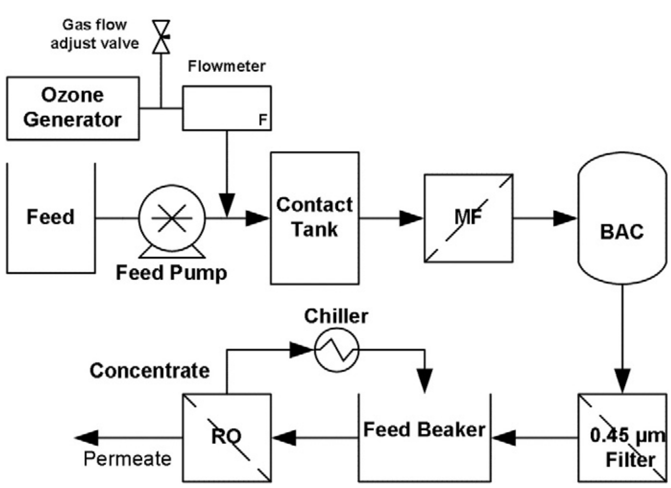

Fig. 1. Schematic for the pretreatment units.

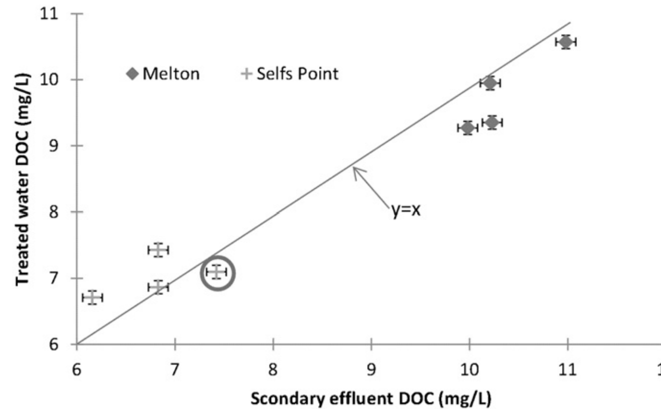

Fig. 2. Influence of ozonation on DOC of secondary effluent.

2. Experimental

2.1. Operation units

The complete process schematic is shown in Fig. 1, but only selected parts of the process were used in individual experiments. The pretreatment units included an ozone generator, an ozone contact tank, a BAC column (the activated carbon, Acticarb BAC GA1000N, sourced from an operating ozone-BAC system in a water treatment plant, VIC, AU), a ceramic MF membrane (effective area 0.0045 m^2; Pall®, 0.1 μm, ZrO_2), and Filmtec® BW30 membranes (effective area of 0.0042 m^2) housed in a Sterlitech flatsheet membrane module.

2.2. Operation parameters

Two wastewater feeds were used in the study. A MF wastewater filtrate from Melton Wastewater Treatment Plant, VIC, AU (activated sludge plant followed by MF) referred to as pre-filtered wastewater was used, and its TOC was in the range of 9.0–10.5 mg/L. Un-filtered secondary sewage effluent from Selfs Point Wastewater Treatment Plant,

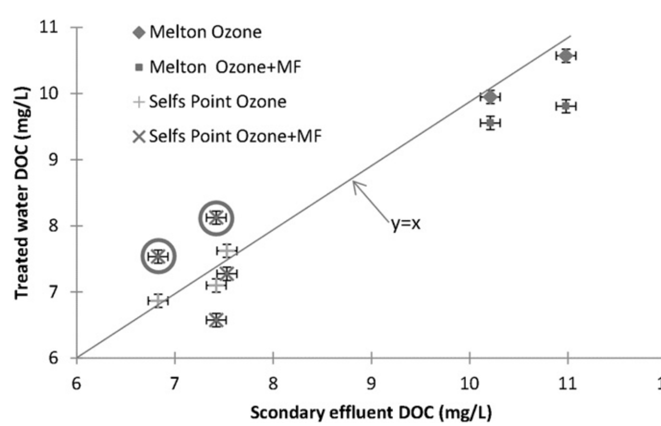

Fig. 3. DOC difference between ozone and ozone + MF pretreated secondary effluent (Two samples in the circles are filtered with fouled membrane).