Pre-treatment of beverage production wastewater using a 5nm TiO2 ceramic ultrafiltration membrane

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Title:

Pre-treatment of Beverage Production Wastewater Using a 5 nm TiO_2 Ceramic Ultrafiltration Membrane

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Abstract: (Your abstract must use **Normal style** and must fit in this box. The abstract should be written in English and should be around 1000 words long, i.e., 2 pages excluding title, authors & affiliations, keywords and references. Authors are encouraged to show important figures/tables etc in the abstract so as to make a full presentation.)

Abstract:

Using membranes to pre-treat wastewater generated by beverage production facilities presents a challenge due to the fact that such wastewater is commonly high in chemical and organic content. The present work evaluated a 5 nm TiO_2 ceramic ultrafiltration membrane with respect to beverage production wastewater. Results show that certain combinations of crossflow velocities (CFVs) and transmembrane pressures (TMPs) provided significant improvements in permeate flux and contaminant rejection rates. These improvements are attributed to the turbulent flow regime experienced by suspended particles during ultrafiltration. The majority of the particles present in the wastewater are swept away from the membrane surface resulting in reduced concentration polarization (cake layer) resistance and improved permeate flux. Similarly, the reduction in particle deposition on the membrane surface also reduces particle infiltration into the membrane pores resulting in better filtrate quality in terms of turbidity and COD.

Introduction:

The present study evaluates the performance of a 5 nm TiO_2 ceramic ultrafiltration membrane with respect to beverage production wastewater. This specific membrane was chosen for the following reasons. Firstly, different cleaning chemicals and detergents are present in the actual wastewater streams and therefore a ceramic membrane is more suitable than a polymeric membrane with respect to chemical stability considerations. Secondly, the active layer of the chosen ceramic membrane (TiO_2) is a good inhibitor of biofilm growth and fouling [1]. This characteristic of the active layer is well suited for wastewater containing a high level of organic contamination – such as the beverage production wastewater which is the subject of this investigation. Lastly, the measured particle sizes present in the actual beverage production wastewater samples ranged from 24 – 5560 nm – making ultrafiltration more appropriate than microfiltration.

Materials and methods:

1. Actual wastewater samples were obtained from the production facility of a beverage producer located in Melbourne, Australia.

2. A Membralox T1-70 single channel ceramic membrane with a titanium dioxide

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(TiO_2) active layer was used in all the experiments. The membrane has a nominal pore size of 5 nm and an effective membrane area of 0.005 m^2.

3. The schematic diagram of the ceramic crossflow ultrafiltration rig used in the experiments is shown in Fig. 1. CFVs used are 2.5, 3.1 & 3.6 ms^{-1}; TMPs used are 100, 200 & 300 kPa.

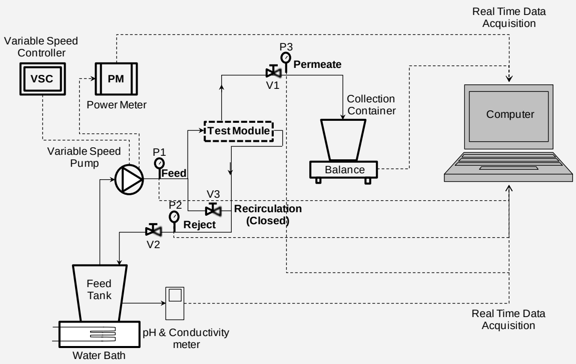

Fig. 1

4. The size distribution and zeta potential (ζ) of particles in the actual wastewater samples were measured using a Malvern Zetasizer Nano Series (Nano-ZS). Chemical Oxygen Demand (COD) was used to assess the contaminant rejection performance of the ceramic membrane while turbidity measurements were used to estimate particle rejection rates.
5. Membrane cleaning was performed after each experiment. Cleaning chemical used was Ultrasil 10 (supplied by ECOLAB Australia).

Results and discussion:

Results from the experiments show that flux improvement during ultrafiltration of beverage production wastewater is dependent on both CFV and TMP (Figs. 2a to c). At the lowest CFV of 2.5 m s^{-1}, the permeate fluxes measured showed minor improvement when TMP was increased to 200 and 300 kPa. At higher TMPs of 200 and 300 kPa, the permeate fluxes measured had high initial values but subsequently went down and reached steady-state conditions after approximately 45 minutes. The steady-state fluxes measured for all TMPs at a CFV of 2.5 m s^{-1} were almost identical to each other. On the contrary, at higher CFVs of 3.1 and 3.6 m s^{-1}, permeate fluxes improved when TMP was increased to 200 and 300 kPa (as shown in Figs. 2b and c). The steady-state permeate fluxes measured at CFVs of 3.1 and 3.6 m s^{-1} increased by 22 % and 53 % respectively when TMP was increased to 200 kPa. Further increasing the TMP to 300 kPa resulted in a 16 % and 4 % increase in steady-state permeate fluxes at CFVs of 3.1 and 3.6 m s^{-1} respectively. This permeate flux behaviour can be attributed to the instability of the particles present in the beverage production wastewater samples. Since the particles have a tendency to aggregate, the larger masses formed are likely to be swept away from the membrane surface due to higher hydrodynamic forces. When the majority of the particles are swept away from the membrane surface, the resistance encountered during filtration lessens - resulting in increased permeate flux.

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a

b

c

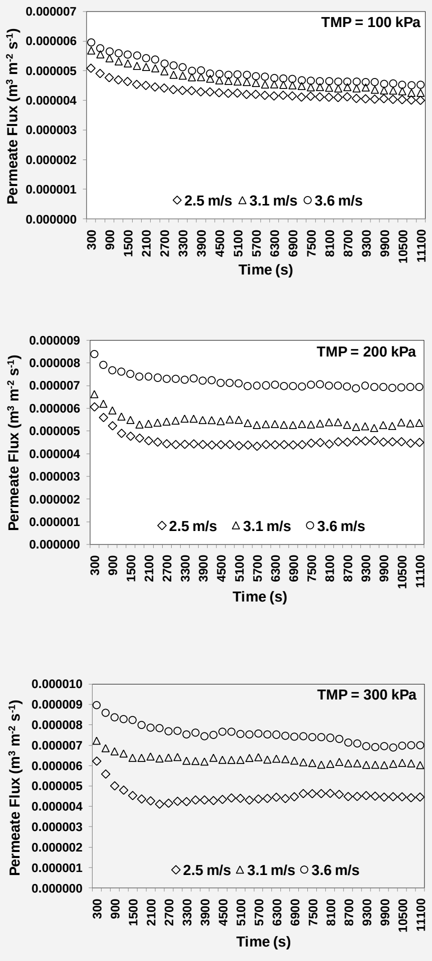

Fig. 2

The influences of TMP and CFV on turbidity and COD rejection rates are shown in Figs. 3a and b. For turbidity, a big increase in rejection rate was obtained at all CFVs when TMP was increased from 100 to 200 kPa. Increasing the TMP further to 300 kPa yielded a slight increase in turbidity rejection rate at all CFVs. Meanwhile, COD rejection rates obtained at all CFVs showed a linear correlation ($R^2 > 0.99$) with TMP. The COD rejection rate of the ceramic membrane may be associated with the suspended particles present in the wastewater samples since an increase in turbidity rejection correlates with an increased COD rejection.

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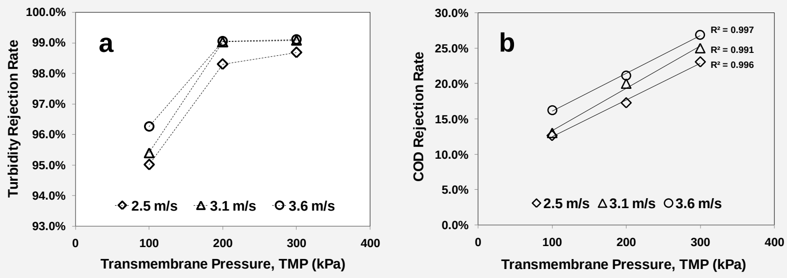

Fig. 3

Conclusion:

A judicious combination of CFV and TMP has been shown to be critical for the successful application of a 5 nm ceramic ultrafiltration membrane to beverage production wastewater. In general, at higher CFVs of 3.1 and 3.6 m s^{-1}, permeate fluxes and contaminant rejection rates show significant improvements when TMP is increased to 200 and 300 kPa. This filtration behaviour can be attributed to the decrease of particle deposition on the membrane surface due to turbulent flow. At the CFVs mentioned, the majority of the particles present in the beverage production wastewater are swept away from the membrane surface resulting in lower concentration polarization (cake layer) resistance and increased permeate flux. Likewise, once the majority of particles are swept away from the membrane surface, their infiltration into the membrane pores is also reduced resulting in lesser suspended solids in the filtrate.

References:

[1] Ciston, S., Lueptow, R. M. & Gray, K. A. 2008. Bacterial attachment on reactive ceramic ultrafiltration membranes. *Journal of Membrane Science,* 320**,** 101-107.