University of Technology, Sydney

Hydrodynamic Study on Fouling Control in Submerged Membrane Microfiltration

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Certificate of Authorship/Originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Dedication

To my late father Gopal Bhagat Pradhan,

His blessed words of encouragement and silent inspiration

in pursuit of excellence, still dwell on me.

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Abstract

Application of air flow is a promising hydrodynamic technique for membrane fouling control in submerged membrane separation systems. This thesis investigates the effect of operating conditions and hydrodynamic parameters on membrane fouling during submerged membrane microfiltration. The experiments were conducted under different operating conditions such as the application of various air flow rates, permeate flux rates, the addition of external materials (granular activated carbon: GAC, ferric chloride: $FeCl_3$) and with different feed properties (varying viscosity) for model feed suspension (kaolin clay). Membrane fouling was examined with the different geometries of air diffuser plates that generate different sizes of air bubbles. Additionally, this study reports on the effect of adsorbents on the removal of organic matter during the microfiltration of synthetic wastewater.

Membrane fouling was evaluated with a popular hydrodynamic approach: the application of air flow in submerged flat sheet membrane microfiltration. The investigation focused on the measurement of transmembrane pressure (TMP), particle deposition (fouling) and particle size distribution to assess membrane fouling under a variety of filtration conditions. The experimental results show that an increase in air flow rate reduces TMP as well as particle deposition for all the operating conditions studied. Conversely, an increase in permeate flux causes higher TMP development. The linear relationship between the TMP and particle deposition has been established for different air flow and permeate flow rates. Based on experiments, a particle deposition mathematical model was developed for a high concentration of kaolin clay in suspension. In the case of a higher viscosity of feed, elevated TMP indicated higher fouling; however, TMP was reduced by increasing the flow of air bubbles (higher air scour).

The high energy requirement for air flow systems is a challenging issue in submerged membranes, and this study therefore suggests alternative techniques for optimising the air flow rate and limiting fouling. The addition of external material (support medium) in the kaolin suspension caused a further reduction in membrane fouling that was the result of air scour only. Almost the same reduction in TMP was obtained by adding a support medium instead of doubling the air flow rate. Therefore, the addition of a support

medium with low air flow could offer a good alternative for the control of fouling in a submerged membrane microfiltration system. Furthermore, different geometries of air diffuser plates had a significant influence on the performance of the submerged membrane microfiltration. Improved reductions in TMP and particle deposition were observed with the circular aerator (small bubbles) rather than the square aerator (large air bubbles). The results in this study highlight that the effectiveness of the air flow depends on the geometry of the aerator plates and the consequent production of different sizes of air bubbles. The optimisation of the combined effect of the support medium and air flow with the appropriate aerator plate geometry will lead to a less energy-intensive operation in membrane microfiltration systems.

This study also separately examines the effect of flocculation and adsorption coupled with submerged microfiltration on membrane performance. The TMP development at optimal flocculant ($FeCl_3$) concentration was significantly less than it was with unflocculated kaolin feed. The addition of flocculant exhibited better control of colloidal membrane fouling due to the modification of the cake properties (cake structure, porosity, and compactness). In the case of an adsorption-microfiltration system with synthetic wastewater, the adsorbents (powder activated carbon: PAC, GAC and Purolite) introduced into the suspension helped to remove organic matter prior to their contact with the membrane. The submerged membrane adsorption system was very effective in removing dissolved organic matter from the synthetic wastewater. Of these three adsorbents, PAC was observed to be the most effective, with a higher level of removal efficiency for dissolved organic carbon. A higher dose of PAC showed an almost 100% reduction of hydrophobic compounds.

A higher air flow rate was always found to be beneficial to membrane fouling control, whereas high viscosity had a negative impact on fouling. High air flow demands high energy, which leads to high operating costs. This research investigated various options to minimise air flow rate. The addition of a support medium (GAC) could be a good alternative to a high air flow rate. The geometry and design of the aerator plate were also very important parameters that directly influenced membrane fouling. More importantly, the flocculation and adsorption used in this study were found to be very effective in the reduction of membrane fouling.