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Intermittency as a Tool for Minimization of Membrane Fouling

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A major challenge in membrane filtration of biomass is that flux declines quickly due to cake formation and membrane fouling, caused by internal or external deposition of the suspended solids. Considering that the key to successful application is flux maintenance or productivity, a possible procedure for flux stabilization, i.e., intermittency, is discussed here. In intermittent operation, the microfiltration cycles from 'on' to 'off' periods provide relaxation and potential removal of cake solids in the 'off' period. The use of intermittency can provide flux enhancement and modest improvement in productivity. Features that maximize the effect include higher frequency of intermittency, higher crossflow velocity, lower transmembrane pressure, smaller membrane pore size, addition of salts and cleaning of the membrane surface. However, in all cases, the initial high fluxes are rapidly lost due to flux decline as cake deposits on the membrane.

INTRODUCTION

Fouling is the most important factor in membrane filtration that has limited the use of this technology in many applications. Fouling is irreversible deposition of material onto or into the membrane, causing loss of flux and altered rejection. Flux is a function of both pore size and pore density. As fluid passes through a membrane, pores become blocked with particles and, therefore, the pore density is reduced resulting in a drop in the filtration rate. Another cause of the flux decline is the accumulation of fouling material, either inorganic [1] or organic [2,3], on the membrane surface. In other words, the overall permeability decay is caused by pore clogging and/or by the formation of a cake on the membrane surface [4]. In addition to flux decline and rejection alteration, fouling reduces efficiency, shortens membrane life and increases operating pressure and cleaning frequency. With a constant pressure pump, membrane fouling will result in a flux decline, while in a constant permeation rate filtration, fouling will cause an increase in pressure drop across the membrane [5].

Control of fouling is of significant importance. Techniques involved are, firstly, pretreatment of feed which can reduce the particulate density onto the membranes and, therefore, reduce fouling [6]. Secondly, membrane regeneration, e.g., washing the membrane with chemicals, can reduce fouling [7]. Thirdly, using operating conditions, e.g., moderate pressure, crossflow, backwashing and pumping permeate, fouling can be controlled [8].

In this paper, intermittent operation or the cycle between on and 'off' periods has been used for fouling minimization. The effect of intermittency on flux enhancement and productivity was elucidated.

EXPERIMENTAL

Activated sludge biomass was used as a model of a highly concentrated suspension. Mixed liquor with suspended solids in the range of 3500-4000 mg/l (density = 1 g/cm^3, viscosity = 1 cp) was obtained from a sewage treatment plant (Penrith Wastewater Treatment Plant, Sydney, Australia) and used as feed. Tests were performed in a crossflow cell using Millipore hydrophilic 0.45 μm (HVLP) membranes. The membrane module was constructed of perspex and possessed a channel with height, width and length of 2, 27 and 80 mm, respectively. The effective membrane area was 19 cm^2. The membranes were supported by an aluminium plate punched with 3 mm holes. A peristaltic pump was used to supply the operating pressure and the feed circulation. For intermittent operation, a solenoid valve was used to stop the permeate flow during the 'off' period. All experiments were conducted in a crossflow cell at 25 kPa with a crossflow velocity of 1.0 m/s, unless otherwise indicated.

The equipment set-up for tests is shown in Fig-

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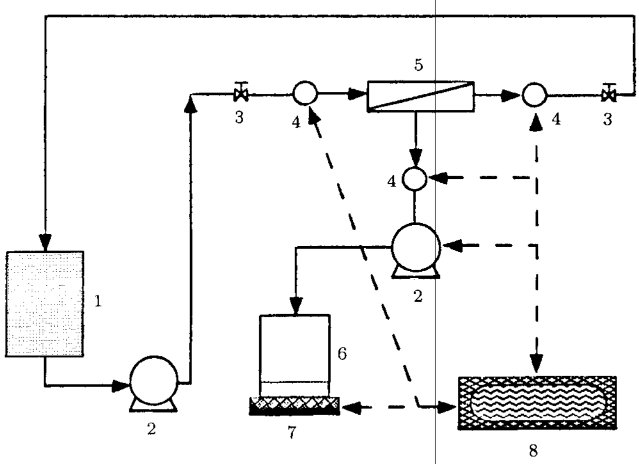
Table 1. Intermittent operation for variable intermittency ratio (HVLP membrane, $\Delta P = 25$ kPa).

Run	Crossflow Velocity in 'on' Period (m/s)	Crossflow Velocity in 'off' Period (m/s)	Intermittency on/off (min/min)	Flux Decline[(a)] (%)	Final Flux[(b)] (l/m^2.h)
1	0.5	0	30/15	70	5
2	0.5	0.5	15/30	50	15
3	1.0	1.0	30/15	38	13
4	1.0	1.0	10/10	45	11
5	1.0	1.0	5/5	24	16
6	1.0	1.0	10/20	35	26
7	1.0	1.0	10/50	22	43

(a) Flux decline (%) = $100 \times (J_{150\,\text{min}} - J_{300\,\text{min}})/J_{150\,\text{min}}$; (b) Flux at 300 min



1. Feed tank 2. Pump 3. Valve 4. Pressure element (transducer) 5. Crossflow cell 6. Permeat 7. Balance 8. Computer

Figure 1. Equipment set-up for pumped permeate tests.

ure 1. Pressure transducers from Labom Company supplied by Tempress Controls (E1301 for P_{in}, P_{out} and E2313 for P_{permeate}) were used for precise measurement of transmembrane pressure. Crossflow rate was controlled by the recirculation pump, while flux was fixed by the permeate pump. Transmembrane pressure was monitored as the independent variable.

RESULTS AND DISCUSSION

Flux Maintenance

The key to successful application is flux maintenance or productivity. The first step in the maintenance of the flux is changing the mode to crossflow. This change can improve both flux and rejection [9]. In crossflow microfiltration, the feed is circulated such that the flow is parallel to the membrane surface in order to limit the build-up of the cake layer and maintain the flux.

In this study, in addition to crossflow mode, the intermittent operation was used as another tool for fouling minimization. The concept here is to create cycles between periods of applied pressure (the 'on' period) and no pressure (the 'off' period). The improvement in performance can occur if the cake relaxes and is partially removed during the 'off' period.

Effect of Variable Intermittency Ratio on Flux

The experimental conditions and flux decline with intermittency ranging from 30/15 to 10/50 are summarized in Table 1. All the experiments were carried out for 5 h. It is best to compare the data over the period of 150 to 300 min (i.e., after the initial changes due to start-up).

Comparison of various runs illustrates that the worst decline was for runs with no crossflow in the 'off' period, i.e., crossflow should continue during the intermittent process. A crossflow of 0.5 m/s showed a decline worse than a crossflow of 1.0 m/s and the least decline was for the highest frequency of intermittency. Increasing the 'off' period (for the same crossflow) decreases the flux decline and improves the final flux.

Flux histories for various intermittencies at a crossflow velocity of 1.0 m/s are presented in Figure 2.

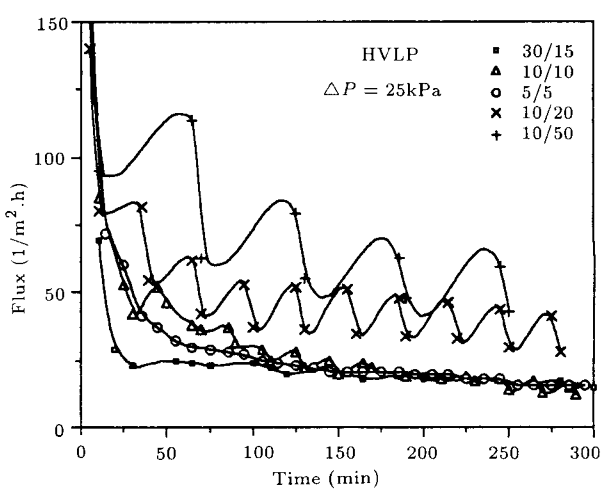


Figure 2. Flux for various intermittencies.

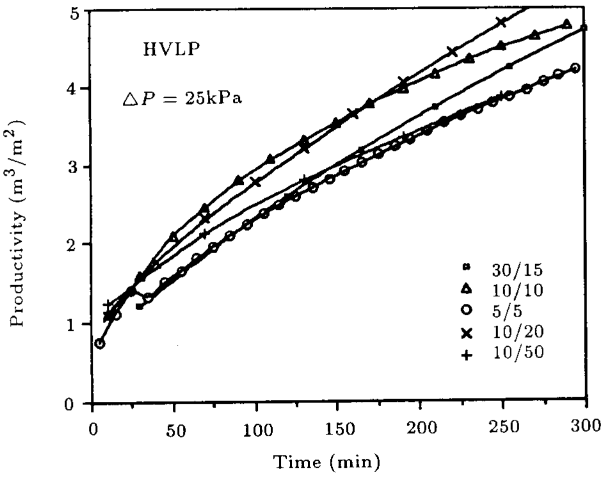


Figure 3. Productivity for various intermittencies.

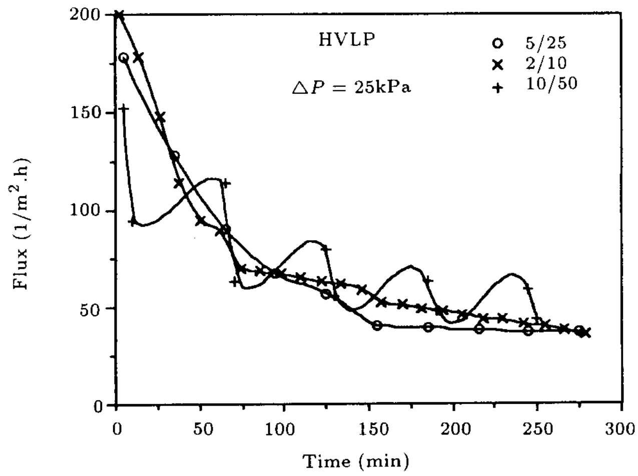


Figure 4. Flux at constant intermittency ratio.

The profiles show that the longer the 'off' period, the greater the recovery and, consequently, the steeper the decline compared to the 'on' period. However, in all cases, there was a steady downward drift in the baseline. In Figure 3, the intermittency data are expressed as productivity per unit time. As expected, intermittencies with long 'off' periods tend to display rather poor productivity despite their high fluxes.

Effect of Variable Permeation Time at Constant Intermittency Ratio on Flux

A set of experiments was carried out for which the 'on' time changed but the intermittency ratio (i.e. on:off time) was kept constant at 1:5. The intermittency times tested were 10/50, 5/25 and 2/10 which are equivalent to 1, 2 and 6 flux periods per hour, respectively. The results are shown in Table 2 and Figure 4. The final flux (Table 2) and the productivity (Figure 5) depict that longer 'off' periods improve performance for a given intermittency ratio. However, the effect is not major and could be attributed to the variation between batches of feed material.

In summary, intermittency can improve the flux. The technique provides an advantage especially if the feed is cake-forming type and adhesive. The optimum conditions are not predictable a priori since the extent of cake removal during the 'off' period cannot be estimated accurately. For a given application, it would be necessary to determine the optimum conditions experimentally. However, if intermittent operation is employed, the productivity may be sacrificed. The practical application of this technique depends on the extent of fouling. If fouling is serious, it is worth losing productivity in order to maintain the flux.

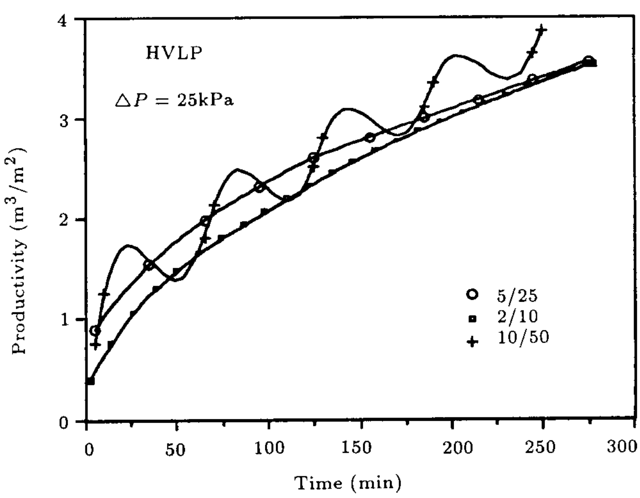


Figure 5. Productivity at constant intermittency ratio.

Table 2. Intermittent operation for variable permeation time at constant intermittency ratio (HVLP membrane, $\Delta P = 25$ kPa).

Run	Crossflow Velocity (m/s)	Intermittency on/off (min/min)	Flux Decline (%)	Final Flux (l/m^2.h)
7	1.0	10/50	22	43
8	1.0	5/25	12	37
9	1.0	2/10	36	32

CONCLUSION

In membrane filtration of biomass, control of fouling is of utmost importance. A strategy for fouling minimization is optimization of operating conditions. Intermittency, in which microfiltration cycles exist between 'on' and 'off' periods, can be used for improved performance. Intermittency provides relaxation and potential removal of cake solids in the 'off' period.

The results demonstrate that the longer the 'off' period, the greater the recovery and, consequently, the steeper the decline compared to the 'on' period. However, intermittencies with long 'off' periods tend to display rather poor productivity despite their high fluxes.

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