ELSEVIER

Desalination 106 (1996) 31–38

DESALINATION

Filter backwash water recycling using crossflow microfiltration

S. Vigneswaran[a*], S. Boonthanon[b], H. Prasanthi[a]

[a]*School of Civil Engineering, University of Technology, Sydney, PO Box 123, Broadway, NSW 2007, Australia*
Tel. +61 (2) 330-1551; Fax +61 (2) 330-1990
[b]*Clean Technology Co. Ltd., 3081/9-10 Lard-Prao Road, Between Soi 111-113, Bangkapi, Bangkok 10240, Thailand*

Received 19 March 1995; 15 June 1995

Abstract

Experiments were carried out using crossflow microfiltration (CFMF) for treating filter backwash water from a water treatment plant. It was found that CFMF with backflush is technically feasible and highly efficient. The condition of the backflush frequency (T_f) of 1 min and backflush duration (T_b) of 1 s was found to be optimum. Long-term experiments showed that partially clogged membranes can also yield significant productivity and that the process is insensitive to varying influent concentration.

Keywords: Filter backwash water; Microfiltration; Backflush frequency; Backflush duration; Productivity

1. Introduction

In a typical water treatment plant, a large quantity of water (2–5% of total water production) is used in backwashing the rapid sand filters. This filter backwash water is high in solids and the general practice of disposal is by using sludge lagoons. While requiring a large land area, this type of disposal causes environmental hazards due to aluminium leaching into the soil. With appropriate treatment, not only the requirement of large land area for disposal would be reduced but also large quantities of high-quality water can be produced which can be recycled back to the water treatment plant.

*Corresponding author.

One of the attractive options for recycling the filter backwash water is by using crossflow microfiltration (CFMF). CFMF is a pressure-driven membrane process where the feed is tangential to the membrane surface. This type of crossflow helps in reducing the clogging of membrane surface thus increasing the efficiency and life span of membranes compared to dead-end filtration.

CFMF is technically a very effective filtration process for separation of colloidal and suspended particles in obtaining high-value products, but its application to water and wastewater treatment is presently limited due to the problems of flux decline resulting from fouling, deposition and

PII S0011-9164(96)00089-6

internal clogging of the membrane. In order to reduce this problem, several declogging techniques are presently being investigated. Preliminary studies showed that backflushing is a very effective declogging technique which helps in reducing the problem of flux decline in CFMF.

In this study the filter backwash water, obtained from the Bangkhean water treatment plant in Bangkok, was used feed. A ceramic tubular membrane was used in the laboratory-scale CFMF membrane system. Backflushing was adopted as an in-line declogging technique which augments the membrane performance.

The main objective of this investigation was to study the feasibility of using CFMF with a periodic backflush technique to treat filter backwash water and produce high-quality water which is recyclable.

2. Experimental

The membrane used in this study was ceramic and had two layers: a membrane layer comprising several layers of well defined texture of porous ceramic and a support layer composed of macroporous layers of α-alumina. Ceramic membranes have a very good chemical resistance (e.g., they can withstand a pH range of 0.5–13.5) and at the same time are capable of sustaining mechanical stress (e.g., burst pressure >30 bars).

In this study a single-channel membrane with an outer diameter of 10 mm, an inner diameter of 7 mm, tube length of 250 mm and pore size of 0.2 μm was used. The total effective permeation area was 4550 mm^2. The membrane was placed inside a tubular stainless-steel membrane housing.

The experimental set-up, as given in Fig. 1, consists of a storage tank from which the filter backwash water was pumped under pressure into the tubular membrane filter. The bypass system was necessary for controlling the operating pressure (ΔP) and crossflow velocity (V_s) at 100 kPa and 3 m/s, respectively. The operational backflush pressure (ΔP_b), which is the difference between backflush pressure and operating pressure, was maintaine d at 100 kPa. The cooling coil was set inside the storage tank and a temperature controller was used to maintain the operating temperature at 30±2°C. The concentrate and the permeate flows were recirculated. The permeate flow collected in a reserve tank was used for backflushing and the excess overflowed to the storage tank. The programmable controller (OMRON SYSMAC-S6) together with solenoid valves were used for automatic operation and control of the membrane filtration process. The equipment also allows the possibility of varying the duration or frequency of backflush to observe their effect on the improvement of the filtrate flux.

3. Definition of terms

In this study, the performance of CFMF is monitored in terms of productivity, improvement in productivity and resistance of the membrane. The definition of these parameters is given below.

$$\text{Productivity} = \frac{\text{Increment in net volume of permeate produced during a particular time}}{\text{Membrane area} \times \text{time interval}}$$

$$\text{Improvement in productivity}\,(I_p)\,(\%) = \frac{\text{Product with backflush}}{\text{Productivity without backflush}} \times 100$$

Assuming that Darcy's law is valid at any moment during filtration, the hydraulic resistance, R, can be defined as:

$$R = \frac{\Delta P}{\mu\,(Q/A)} \tag{1}$$

At a given moment of filtration, the total resistance, R_F, is the sum of the resistance of the clean membrane, R_M, and of the resistance due to

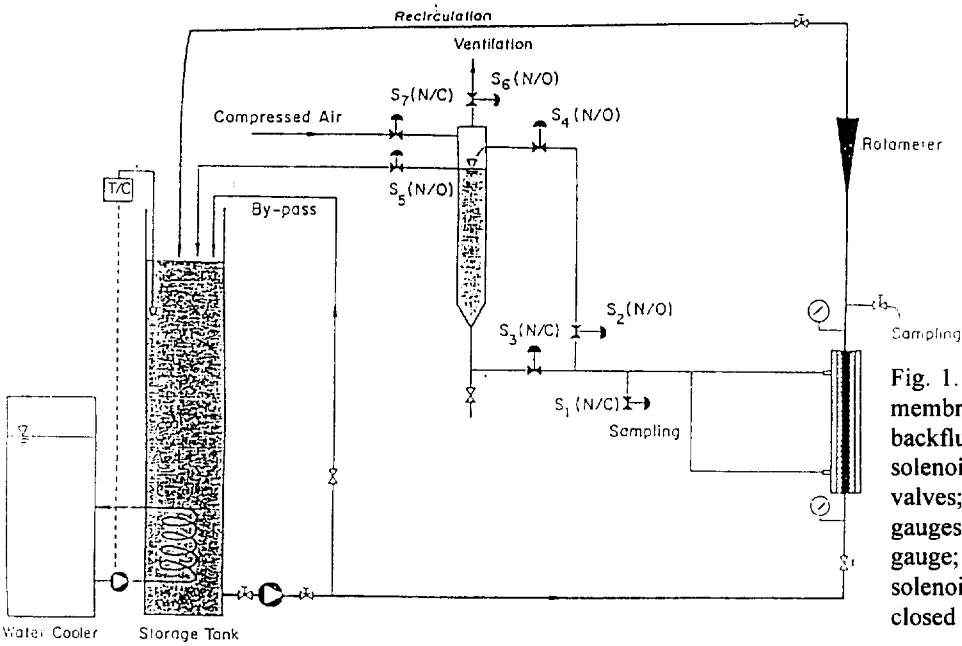

Fig. 1. Experimental set-up of membrane unit (with periodic backflush system): S1–S7, solenoid valves; V1–V6, ball valves; P1–P2, system pressure gauges; P3, backflush pressure gauge; N/O, normally open solenoid valve; N/C, normally closed solenoid valve.

all the fouling phenomena, R_O (the fouling is due to internal clogging, deposits, etc.). The unit of resistance is m^{-1}.

$$R_F = \frac{\Delta PA}{\mu(d\sum V_t/dt)} = \frac{\Delta PATf}{\mu V_t} \qquad (2)$$

where ΔP is the operating pressure, Pa; A the effective membrane area, m^2; μ the viscosity of the liquid flowing through membrane, Pa-s; Q the permeate flow rate, $m^3\ s^{-1}$; Tf the time interval of CFMF operation, s; V_t the total volume of permeate filtered during Tf, m^3; and $(d\Sigma V_t)/dt$ is the rate of permeate production, m^3/s.

For quantifying the efficiency of backflush, a resistance index (RI) is proposed,

$$RI = \frac{R_F - R_M}{R_O - R_M}$$

where R_F is the resistance with backflush, R_O the resistance without backflush and R_M the resistance with clean water.

R_F and R_O are both taken for the same value of the volume filtered. The value of RI is less than 1; when RI approaches 1, it implies that the backflush is inefficient. A smaller RI means efficient backflush, and a zero value would mean a perfectly efficient backflush.

4. Results and discussion

The performance of CFMF in treating filter backwash water was evaluated in terms of productivity and improvement in productivity. The resistance of the membrane also has been used to show the superiority of using backflushing as a declogging technique in recycling filter backwash water.

Backflushing is a very efficient process of declogging. The time interval and duration of backflush are the main operating parameters which effect the performance of CFMF. In this study three different backflush durations (T_b=1, 2 and 5 s) and three backflush frequencies (T_f=1, 2 and 3 min) were chosen based on the preliminary experiments [1]. The other operating conditions such as crossflow velocity, transmembrane pressure during filtration and differential pressure for backflushing were all maintained constant at 3 m/s, 100 kPa and 100 kPa, respectively.

4.1. *Effluent quality*

In all the experiments carried out, the characteristics of effluent from the CFMF process were found to be superior. Table 1 presents the comparison of characteristics of clarified water obtained from CFMF with those of filter backwash water.

Table 1
Water characteristics

Parameters	Filter backwash water	CFMF effluent
Turbidity, NTU	200–300	0.2–1.5
pH	7.4–7.8	6.8–7.4
MPH/100 ml	120,000–180,000	0
Aluminium, mg/l	205.5	<acceptable range

As can be seen from the table, the quality in terms of turbidity is very high; the turbidity of effluent varies only from 0.2 to 1.5 NTU. Almost all bacteria are removed with MPN/ml in the effluent being zero. Presence of aluminium in the filter backwash water when discharged into the sludge drying lagoons poses many direct and indirect detrimental effects on humans, plants and soil. With CFMF, all aluminium is removed from the water. The sludge obtained in this process is very high in solids and can be disposed of by using appropriate methods.

Thus, CFMF is a superior process in terms of treating and recycling filter backwash water.

4.2. *Comparison in terms of productivity*

The performance of CFMF first in terms of productivity is presented in Fig. 2. The productivity which is the increment in net volume at a given time per unit membrane area at a given time interval is plotted against CFMF operation time. It can be observed from the figure that the performance of CFMF with backflush is always superior to CFMF without backflush. In addition,

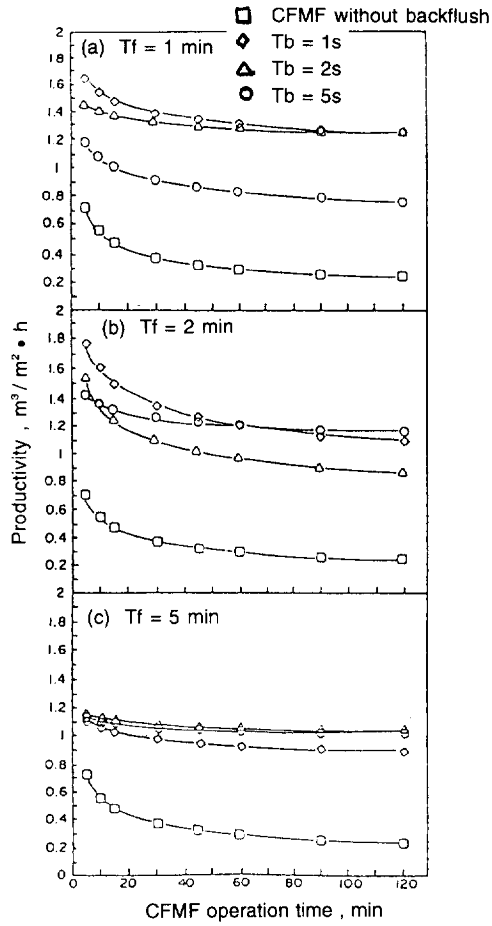

Fig. 2. Variation of productivity with CFMF operation time at different backflush durations (T_b) and frequencies (T_f) (filter backwash water as suspension, Vs= 3 m/s, ΔP=100 kPa, ΔPb=100 kPa, dm=0.2 µm, area of membrane=0.00455 m^2; temperature=30±2°C.

it can be stated that the smaller the backflush frequency and duration, the better is the efficiency of CFMF. Thus the highest productivity was obtained for T_f=1 min, T_b=1 s followed by T_f= 1 min, T_b=2 s. These results show that frequent backflushing of short duration leads to better CFMF performance.

4.3. *Comparison in terms of improvement in productivity*

In order to assess the process more rationally,

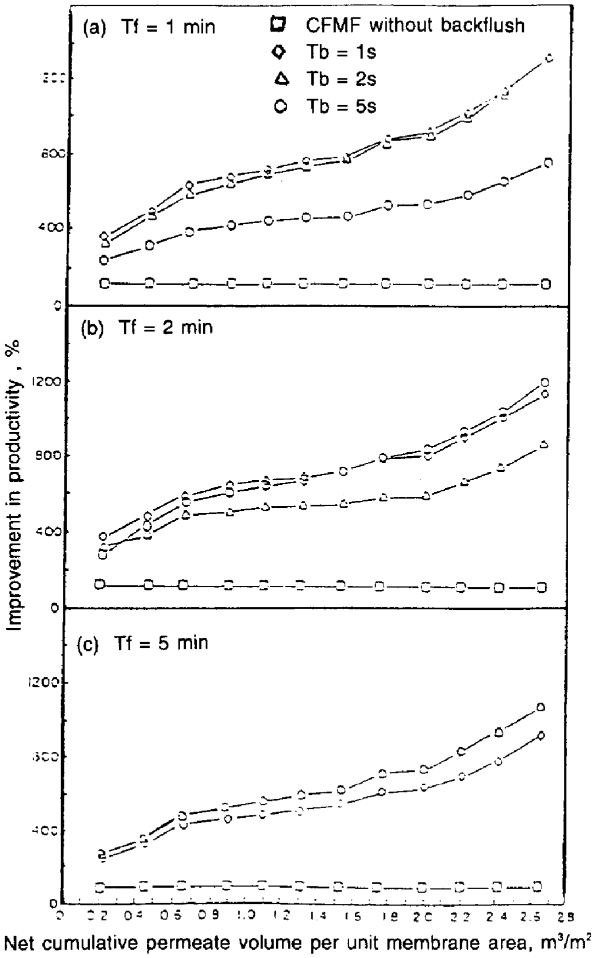

Fig. 3. Variation of improvement in productivity (I_p) due to backflush with net cumulative permeate volume per unit membrane area (filter backwash water as suspension, Vs=3 m/s, ΔP=100 kPa, ΔPb=100 kPa, dm=0.2 μm, area of membrane=0.00455 m^2; temperature=30±2°C).

the improvement in productivity, I_p, in percentage was calculated. Fig. 3 presents the variation of improvement in productivity with the net cumulative permeate volume obtained for each backflushing condition. This figure clearly depicts the use of shorter filtration time and backflush time in maximizing the efficiency of the process tremendously. The I_p curve for T_f=1 min, T_b=1 s is not only the best but also has an increasing trend along with the volume filtered. The I_p values are quite high, about 250–1200% more than that of CFMF without backflush, for the above mentioned best operating conditions. Following this, the operating condition of T_f= 1 min, T_b=2 s is the second best, as can be seen from the figure. The I_p values are almost the same as the first condition (210–1200%). This high percentage of improvement is attributed to the presence of aggregates in the filter backwash water. It is interesting to note that similar experiments with natural surface water yielded an I_p of only 100–250% [2]. The structure and mechanical strength of aggregates allow for more enhanced surface deposition than internal clogging during these experiments.

4.4. Comparison in terms of resistance index

Fig. 4 shows the variation of hydraulic resistance obtained in terms of productivity with total cumulative permeate volume per unit membrane area. As can be seen from the figure, the resistance for CFMF without backflush is very high compared to that with backflush.

Further, the RI is a clear indication of the performance of the membrane under the conditions of clogging. This allows the assessment of filtration quantitatively by comparing the performance at a fixed value of total cumulative permeate volume. In this case, the process was observed to be stabilized after a volume of about 2.637 m^3/m^2 was filtered. The values of RI calculated at this point for different operating conditions, calculated from Fig. 4, are tabulated in Table 2. From the results it is clear that the RI values observed are very low.

All the above results show that CFMF with backflush is a technically feasible method to treat and recycle filter backwash water. The productivity of 1 m^3/m^2.h is significantly higher compared to any other membrane applications.

4.5. Long-term experiments

A continuous batch of experiments was carried out varying different operating parameters.

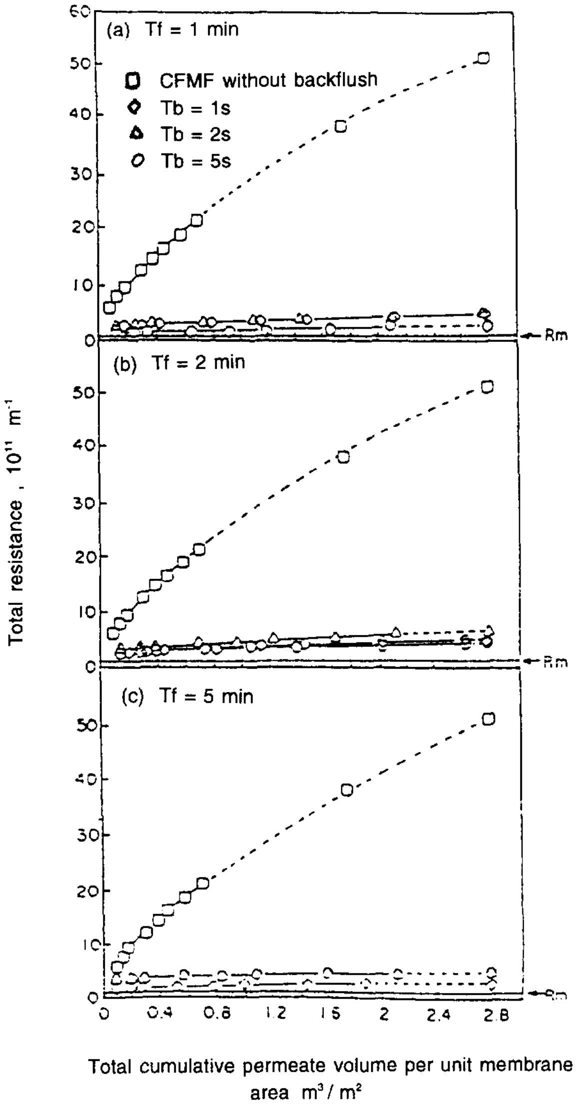

Fig. 4. Variation of total resistance with total cumulative permeate volume per unit membrane area (filter backwash water as suspension, Vs=3 m/s, ΔP=100 kPa, ΔPb=100 kPa, dm=0.2 μm, area of membrane=0.00455 m^2; temperature=30±2°C, dotted line represents extrapolation).

These experiments were conducted at the optimum backflush conditions of T_f=1 min, T_b=1 s. Some experiments were carried out maintaining the influent concentration constant. This is achieved by recycling the permeate back to the influent tank. In another set, the influent concentration was varied which is achieved by not recycling the permeate back to the influent tank. Other batch experiments with varying pressure (varying from 50 kPa to 100 kPa) were also carried out. The crossflow velocity for filtration and backflushing were maintained the same as the other experiments.

Table 2
Summary of resistance index (at total cumulative permeate volume per unit membrane of 2.637 m^3/m^2) at different backflush conditions

T_f, min	T_b, s	RI
1	1	0.047
	2	0.047
	5	0.007
2	1	0.057
	2	0.085
	5	0.047
5	1	0.027
	2	0.068
	5	0.068

The results obtained in these experiments are plotted in Figs. 5 and 6. The following conclusions can be drawn from these figures:

1. With a rather clean membrane, it was found that the higher the influent concentration, the smaller the permeate flux (see experimental results in region A of Fig. 5).

2. With a partially clogged membrane, it was noted that CFMF performance is relatively insensitive to the influent concentration. Experimental results in region B of Fig. 5 confirmed this conclusion.

3. It was noted from the present experiments that the polarization phenomenon does not exist since the linear relationship between the productivity and operating pressure was established, as can be seen in region C of Fig. 5. and further plotted in Fig. 6.

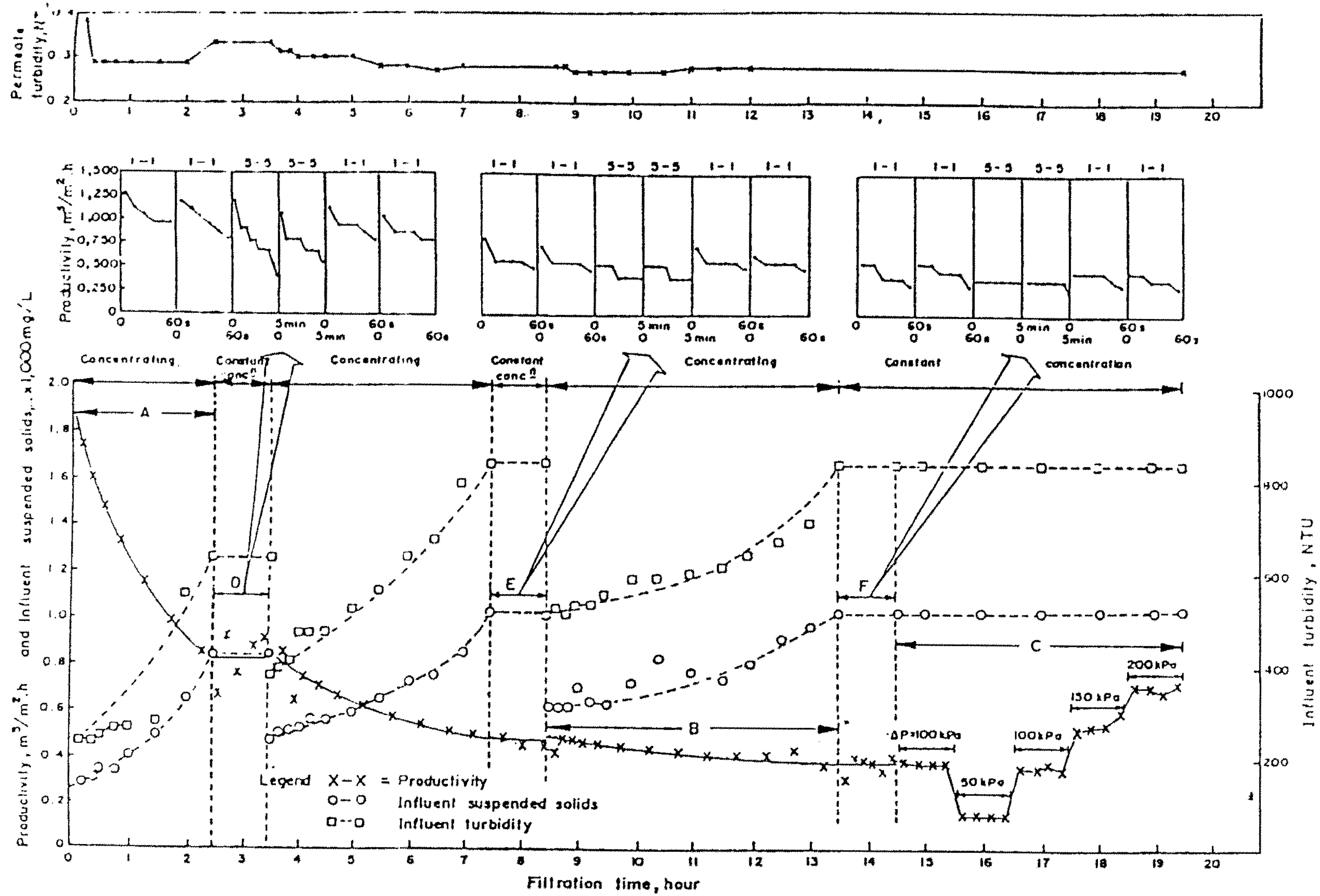

Fig. 5. CFMF performance with backflush technique in treating filter backwash water during 20 h operation (Vs=3 m/s, ΔP=100 kPa, ΔPb=100 kPa, dm=0.2 μm, area of membrane=0.00455 m^2; temperature=30±2°C, T_f=1 min and T_b=1 s or otherwise specified in the figure).

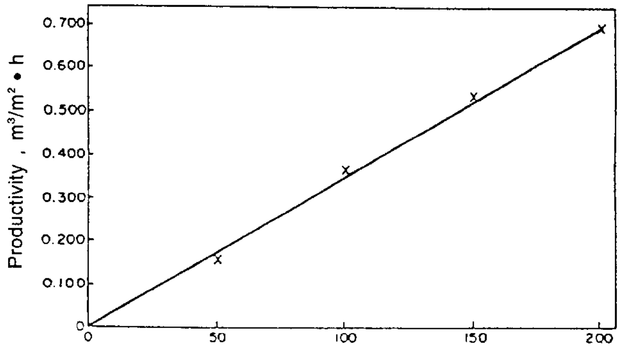

Fig. 6. Relationship between productivity and operating pressure (ΔP=100 kPa, ΔPb=100 kPa, dm= 0.2 µm, area of membrane=0.00455 m^2, temperature =30±2°C, T_f=1 min and T_b=1 s).

5. Conclusions

The filter backwash water treatment using CFMF is technically feasible. The particles in the suspension entering a rapid sand filter are deposited on the filter grains in the form of aggregates. These aggregates find their way into the backwash water, and the ability of these aggregates to be separated in a CFMF process is thus very high. In this process, high productivity can be achieved using a small area of membrane enabling large quantities of filter backwash water to be treated and recycled. In addition, backflushing during CFMF with periodic backflush enhances membrane performance significantly. In the present experiments, the condition of backflush frequency (T_f) of 1 min and backflush duration (T_b) of 1 s was found to be optimum in terms of increase in productivity. In terms of a resistance index, all the experiments with backflush technique had very low values, indicating that this technique is highly efficient in treating filter backwash water.

In long-terms experiments over a period of 20 h, it was found that significant amounts of permeate can be obtained with a partially clogged membrane, as the process was found to be insensitive to the influent concentration. A linear relationship between operating pressure and productivity shows that the concentration polarization phenomenon is absent in these experiments.

In summary, it can be said that crossflow microfiltration with backflush as a declogging technique is a highly feasible process for treating and recycling filter backwash water. The characteristics of filter backwash water, especially the presence of aggregates, makes this process more attractive as they are removed more efficiently by the microfiltration membranes.

References

[1] S. Boonthanon, Declogging of CFMF membranes: Applications in water and wastewater treatment, D. Eng. Thesis, Asian Institute of Technology, Bangkok, 1991.

[2] S. Boonthanon, H. Prasanthi, S. Vigneswaran and R. Ben Ami, J. Water Supply Res. and Technology - AQUA, 40 (1991) 103.