Influence of the backwash cleaning water temperature on the membrane performance in a pilot SMBR unit.

L. Lintzos[1], K. Chatzikonstantinou[2], N. Tzamtzis[3*], S. Malamis[4]

[1] Postgraduate student in the School of Chemical Engineering, Department of Chemical Science, NTUA, 15780, Greece. Tel. +30-210-7724470, email: loukaslintzos07@gmail.com

[2] Dr. Engineer of NTUA (PHD Thesis in the School of Chemical Engineering, Department of Chemical Science), NTUA, 15780, Greece.Tel. +30-210-9957339 , email: coolwater@otenet.gr

[3] Professor in the School of Chemical Engineering, Department of Chemical Science, NTUA, 15780, Greece. Tel. +30-210-7723194, email: nipitz@central.ntua.gr,

[4] Lecturer in the School of Civil Engineering, Department of Water Resources and Environmental Engineering , NTUA, 15780, Greece Tel: +30 210 772 2797; Fax: +30 210 7722899 email: smalamis@central.ntua.gr

[*]Correspondence author

Abstract

Membrane bioreactor systems (MBRs) have proven to be an appropriate solution nowadays in wastewater treatment, enhancing the conventional secondary treatment stage to a tertiary one. The major advantages of MBR technology over the conventional one, are the production of a high quality effluent, the small space required for the unit installation and the easy automation for more reliable treatment procedure. The most crucial drawback is the membrane fouling. This leads gradually to the system performance decrement, and the increment of the operation cost due to the higher membrane aeration needs, by energy consuming air blowers. Due to the above mentioned reason many manufacturers, depending of the membrane type, recommended alternative cleaning procedures which extend the membrane lifespan and ensure the continuous operating of the MBR system. One of the most common physical membrane cleaning methods is backwash cleaning. During backwash cleaning procedure, aqueous solutions or air flow are driven in reverse order, through membranes. In this study, a backwash cleaning method is performed, using pure water at different temperatures (18, 28 and 38^{o}C) applied on identical hollow fiber (HF) membranes. The influence of backwash water temperature in trans membrane pressure (TMP) and flux values, which are the fundamental membrane operating performance parameters, (recorded before and after cleaning procedure) were examined. It was found that the membranes presented better operating performance (after the cleaning procedure), as the water backwashing temperature was increased. Specifically, the average rate of flux was increased by 11.8% whereas the average rate of TMP was decreased by 11.75% at 18^{o}C cleaning procedure. At elevated temperatures (28and 38^{o}C) the average rate of flux was increased by 12.8% and 16.9% and the average rate of TMP was decreased by 15.9% and 18.9% respectively.

Keywords: backwash cleaning, hollow fiber membranes, TMP, flux.

Introduction

The flow resistance in the mixed fluid through the membrane is known by the broader term ''membrane fouling'' (Judd 2006) [1]. This is caused, by various forms of biomass particles (in dissolved or suspended form), adsorbed on the surface or in the pores of the membrane resulting the membrane fouling effect. The membrane fouling is probably the most important problem which exhibits in the MBR systems and affects operating cost (Zhang et al. 2006a) [2] due to the frequent membrane cleaning and the increased their aeration demand on. Membrane fouling results to a biofilm formation all around the membranes, which gradually increases the permeate flow resistance and reduces the permeate flow (flux). To address this, a greater suction pressure is applied to maintain a constant flow of filtrate. There are many methods for cleaning the membranes in order to prolong their duration and increase their operation lifetime. It has been found in literature that backwash cleaning procedures successfully remove the majority of reversible contamination and partly dislodge loosely adherent aggregates sludge from the membrane surface returning the membrane in good operating condition (Bouhabila et al, 2001 [3], Psoch and Schiewer, 2005a [4], Psoch and Schiewer, 2006) [5]. These cleaning procedures are particularly effective for the removal of accumulated sediments over the membrane surface, which mainly constitutes the reversible contamination, since the resistance of resources are not completely eliminated. After the backwash cleaning process, the membrane recovers part of its initial permeability and their fundamental operating parameters. However, with time, an irreversible loss of membranes productivity is observed, using the above cleaning procedures particularly when the system operates at high filtration rates. (Hai, Yamamoto, 2011) [6].

The frequency, the duration and their ratio in the backwashing process, are the key for the design the backwashing programs which have proven more effective in several studies (EUROMBRA, 2006) [7]. The optimal duration of a backwash cleaning process is scheduled when a full movement of the reversible precipitate on the membrane surface is done. For an MBR system working with hollow fiber membranes supplied with synthetic waste, the optimal interval between cleaning procedures is when the TMP exceeds by 3% the max allowable pressure by the manufacturer (Smith et al, 2005) [8].

In recent literature, there is a lack of experimental data for the influence of pure water at various temperatures on the membrane performance as well as in operating waste water treatment plants. In addition in all previous studies the backwashing procedures use as backwash, the permeate flow (or aqueous solutions of chemicals) at ambient temperature. In this work pure water at three different temperatures, was used for backwash cleaning and the performances of the membranes after cleaning are given and compared.

Materials and Methods

Three identical HF type membranes were used in this study, the characteristics of which are presented in Table 1. The recommended by manufacturers operating membrane conditions and the experimental conditions used in this study are presented in Table 2.

Table 1. HF Membrane Characteristics

Membrane Type	**HF**
Filtration Type	UF
Membrane Material	RPVDF
Pore Size (μm)	0.1
Membrane Area (m^2)	0.05
Frame Dimensions (mm)	24x22
Critical Flux (L/m^2H)	25

Table 2: Operating and experimental conditions recommended by manufacturer

Conditions	**Manufacturer recommended value**	**Experimental value**
Working Time/Cycle (min)	8	8
Relaxing Time/Cycle (min)	2	2
pH	2-13	7-8
Bubble type	Coarse	Coarse
Max TMP (mbar)	200	220
MLSS (mg/lt)	7,000-12,000	7,000-12,000
Backwash Period/frequency	1 time/day	see exp. proced.
Backwash recommended flow (L/hm^2)	30	30
Max Backwash Pressure (mbar)	1000	<50
Suggested Temperature (^oC)	5-40	18, 28, 38

In this experimental study it was chosen to apply the backwashing procedure when the membranes presented significant clogging by recording the TMP value (must not exceeded 220 mbar) and the flux value (must not be dropped below (10 L / m^2h). The pilot plant which was used is presented in Fig. 1.

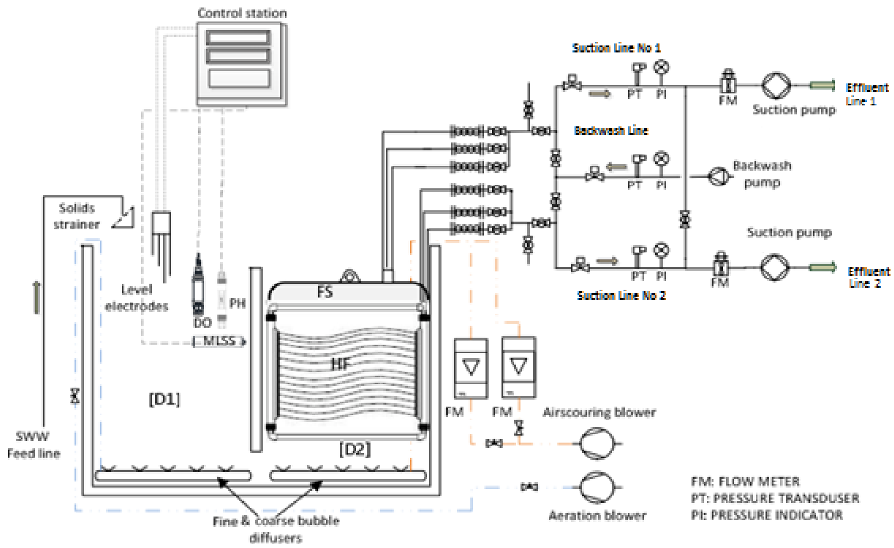

Fig. 1 MBR pilot plant and backwashing layout.

During the normal MBR procedure, in each HF membrane was applied a vacuum suction through a peristaltic, suction pump (0.975-9.750 L/H). Each HF membrane is controlled by an independent suction line. At the exit of each effluent line a glycerin pressure indicator is installed (-1 ÷ 0 bar) and also an analog vacuum pressure transducer (-1 ÷ 0 bar) in series with an analogue flow meter (FM). The working and relaxing time of the suction pump as well as the operating pressure of each suction line (-100 ÷ -500 mbar) were adjusted according to the manufacturer for the protection of HF membrane elements. In the backwash line there are in series a flow control solenoid valves, a glycerin pressure indicator and a analog pressure transducer (0 ÷ 1 bar). The backwash pump was connected to a volume calibrated water container which it was supplied with a regulated thermostat and an immersed heater. The backwash pump was calibrated manually to provide the recommended rate of backwash cleaning water. It should be noticed that the pilot MBR unit treats continuously and for a long period a synthetic urban wastewater under limited aeration conditions for a faster simulated membrane fouling. The MBR unit working conditions are given elsewhere (Chatzikonstantinou et al, 2015) [9]

Experimental procedure

Three experimental cycles were performed. In each experimental cycle three HF membranes were used working continuously at a scheme of eight minutes working period filtration and of two minutes relax period. During the first experimental cycle the back wash water temperature was 18^{o}C in all three membranes. In the second and third cycle the back wash water temperature used was 28 and 38^{o}C respectively. In each experimental cycle the same backwash procedure (having a 3 min backwash period) was performed separately at once in each of the three identical membranes in order to check the repeatability of this cycle. The recorded TMP and flux data are presented as mean values at each examined temperature.

Results and Discussion

In Fig. 2 each bar presents the percentage decrease of the TMP mean value and the percentage increase of the Flux mean value of the same three membranes in each experimental cycle of different water cleaning temperatures.

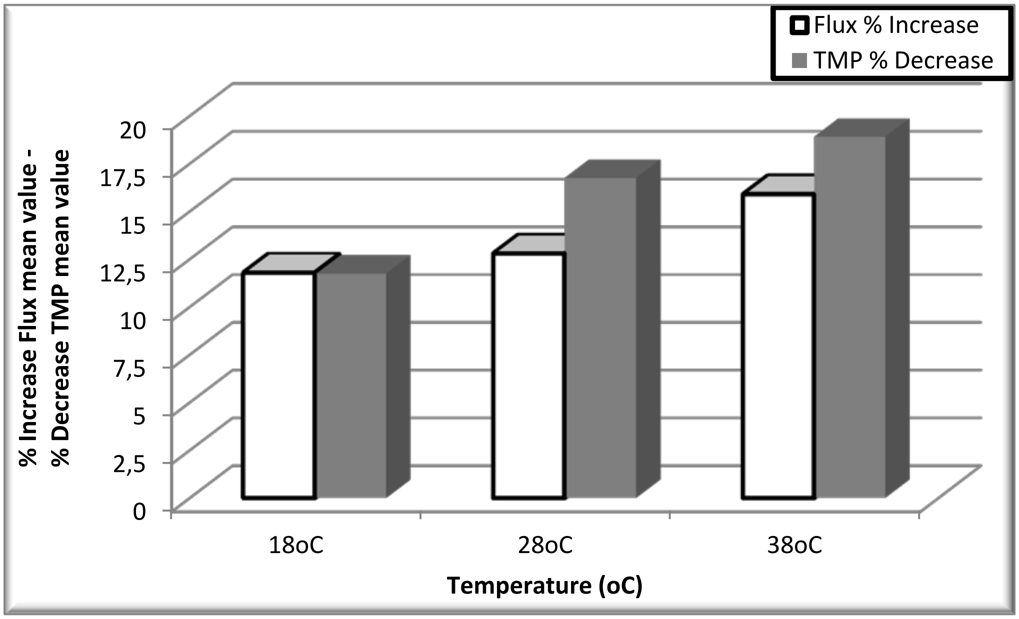

Fig. 2: Mean Value of % TMP decrease and Mean Value of % Flux increase (with respect to values before the cleaning procedure) after backwash the HF membranes with water of 18,28, and 38^{o}C.

It is shown that the membranes which were treated by backwash water at 18^{o}C results a decrease TMP of about 11.75%, and correspondingly an increase of flux rate of about 11.8%. By increasing the backwash water temperature at 28 and 38^{o}C the TMP showed a decrease of 16.75 and 18.93% and the filtration flux an increase of 12.8and 15.91% respectively. In recent references there are no scientific studies like above, so the results could not be compared with other works in the field.

Conclusion

The experimental results of the above study were positive, in all of the examined backwash water temperatures. It was found that the membranes (after the cleaning procedure) presented better operating performance as the backwashing temperature of pure water was increased. In particular, increasing the water temperature from 18 to 38^{o}C a relative reduce of the TMP by 60.8% and simultaneously a relative increase of the flux by 34.7% is observed. All the above must be considered encourages to the direction of the use of environmental friendly chemicals (like pure water or other alternative non toxic aqueous solutions) for membrane cleaning in MBR units. Chemical analysis in effluent quality as well as in biomass, performed simultaneously with the cleaning procedure, could be promoting the above research.

References

[1] Judd S., (2006). The MBR Book: Principles and Applications of Membrane Bioreactors in Water and Wastewater Treatment, Elsevier, Oxford, England.

[2] Zhang J.S., Chuan C.H., Zhou J.T., Fane AG, (2006) Effect of sludge retention time on membrane bio-fouling intensity in a submerged membrane bioreactor, Separation Science and Technology, vol. 41, no. 7, pp. 1313 - 1329

[3] Bouhabila E.H., Ben Aim R., and Buisson H. (2001) Fouling characterization in membrane bioreactors. Separation and Purification Technology 22: 123-132.

[4] Psoch C. and Schiewer S. (2005a) Critical flux aspect of air sparging and backflushing on membrane bioreactors. Desalination and Water Treatment 175: 61-71.

[5] Psoch C. and Schiewer S. (2006) Resistance analysis for enhanced wastewater membrane filtration. Journal of Membrane Science 280: 284-297.

[6] Hai, F. I. & Yamamoto, K. (2011). Membrane Biological Reactors. In P. Wilderer (Eds.), Treatise on Water Science (pp. 571-613).UK: Elsevier.

[7] EUROMBRA, (2006) Membrane bioreactor technology (MBR) with an EU perspective for advanced municipal wastewater treatment strategies for the 21st century, Sixth Framework Programme, Contract No. 018480, Deliverable Report – D5,

[8] Smith P.J., Vigneswaran S., Ngo H.H., Ben-Aim, R., and Nguyen H.(2005) Design of a generic control system for optimising back flush durations in a submerged membrane hybrid reactor. Journal of Membrane Science.255 (1-2):99-106.

[9] Chatzikonstantinou K, Tzamtzis N., Pappa A., Liontakis S., (2015) Membrane fouling control using high-frequency power vibration, in an SMBR pilot system—preliminary studies, Desalination and Water Treatment ,Page 11550-11560