Anaerobic/Aerobic(AnMBR/AMBR)Membrane Bioreactor Treatment for Textile Wastewater

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Abstract

Membrane bioreactors MBRs emerged as promising technology for wastewater treatment. Nevertheless, neither a single aerobic nor a single anaerobic MBR are able to achieve water quality for reuse in the textile sector due to the recalcitrant nature of the wastewater. Therefore this work investigated the performance of a combined anaerobic/aerobic MBR treatment process for textile wastewater which has not yet been studied in literature. The present study was conducted in a laboratory-scale bioreactor with a side-stream membrane module using a model dye wastewater. Besides a commercial UF also the performance of a loose NF membrane was studied. The COD removal improved from 87% to 97% and from 95% to almost 100% for the UF and NF membrane respectively. 98% and 85% of colour were removed by the anaerobic step and the remaining amount has been completely eliminated through the second aerobic step. No significant membrane fouling was noticed neither for the anaerobic nor for the aerobic process.

Keywords
Textile industry; wastewater, combined anaerobic/aerobic membrane bioreactor (AnMBR/AeMBR) process; dye removal

INTRODUCTION

Textile industry is known to be a huge water consuming sector. In fact for the production of a ton of textile product, 200-350 m^3 of water are required (Judd et al., 2003; Schoeberl et al., 2005). Thus, the large quantity of aqueous waste generated by textile industries has become a significant environmental issue. Dye bath effluents in particular are not only visible pollutants by the nature of their colour, but can hinder light penetration in the water of lakes, rivers or lagunas and therefore can disrupt biological processes in natural waters. Therefore dye rejection is among the most important issues regarding water treatment in this industrial sector. On the other hand water reuse is now widely accepted as a sustainable option to respond to the general increase of water demand, water shortages and for environmental protection. Moreover the water energy nexus is becoming increasingly important due to higher energy demand and climate change. Although different chemical, physical, and biological treatment alternatives have been studied to remove dyes from textile wastewaters, biological methods are commonly considered to be the most effective and environmentally safe (Yurtsever et al., 2015).

In the past two decades MBR technology is recognised as a promising technology to provide water with reliable quality for reuse (Hoinkis et al., 2012). MBRs are robust, simple to operate and even more affordable. Even though anaerobic MBR (AnMBR) may increase the color removal performance, aerobic MBR (AeMBR) has been generally used in several lab and pilot scale studies (Yigit et al., 2009). Only very few studies on AnMBR technology for the treatment of textile wastewater are reported in literature (Yurtsever et al., 2015). However, neither a single aerobic nor a single anaerobic MBR is able to achieve water quality for reuse due to the recalcitrant nature of textile wastewater. Additionally membrane fouling is one of the most important obstacles for AnMBR which needs to be further studies. Therefore the objective of the present paper was to focus on the performance of a combined anaerobic/aerobic MBR process and it proved being an efficient solution for this issue. Such a combined treatment process has not been studied yet in the literature.

MATERIALS AND METHODS

The experimental work was carried out in a laboratory-scale bioreactor (Figure 1); namely in a side stream flat-sheet filtration unit named "BIOSTAT® C-DCU" provided by the company Sartorius AG. The MBR unit is composed of a jacketed stainless steel tank with a capacity of 30L with a mass flow controlled aeration, an air inlet filter, a feed controlled by weight sensor among many other sensors that allows to keep the system controlled such as dissolved oxygen sensor, temperature, turbidity, pH, electrical conductivity. The unit was connected to a digital control unit (DCU).

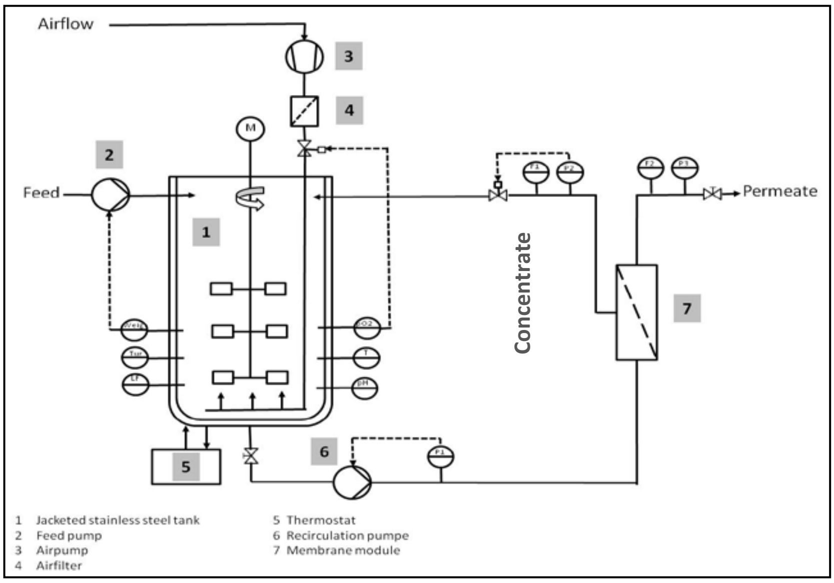

Figure 1. Schematic representation of the side stream MBR unit.

The cross-flow flat-sheet filtration unit (membrane area 0.00856 m^2) was fed by use of a frequency controlled recirculation pump. The concentrate was returned into the tank and the permeate was drained for subsequent chemical analyses. COD, TOC, TN, and colour analyses were performed during the whole experimental period. Due to paper limitation only a focus on COD and colour removal is briefly highlighted in this paper. The work was conducted using a model textile wastewater (MTDW) in order to keep the feed composition constant. Hereby the MTDW was first treated under anaerobic condition. The treated MTDW of the anaerobic step was collected, stored in a refrigerator and subsequently used for the aerobic treatment. Besides glucose as C-source and the salts such as NaCl, $NaHCO_3$, NH_4Cl (N-source) the MTDW was composed of two commercial dyes (50 mg/L each) namely a red azo dye (Acid Red 4) and a blue anthraquinone (Remazol Blue R). The MTDW was characterised prior and after anaerobic treatment (Table 1). The effluent of AnMBR served as feed of subsequent AeMBR step.

Table 1. Characteristics of Model Textile Dye Wastewater (MTDW).

Parameters	Unit	Measured values for anaerobic feed	Measured values for aerobic feed
pH		7.5 ± 0.5	7.5 ± 0.5
COD	mg/L	6732 ± 80	700 ± 25
BOD_5	mg/L	2387 ± 298	-
Total - N	mg/L	78 ± 8	84.1 ± 3.5
Conductivity	mS/cm	5.8 ± 0.15	7.7 ± 0.15

The study investigated two commercial membranes supplied by Microdyn Nadir. The membrane characteristics are given in Table 2. On the one hand a UF membrane which is typically used for submerged MBR application and on the other hand “loose” NF membranes were studied. In general NF membranes have the advantage of higher dye rejection and partial salt rejection compared with UF membranes.

Table 2. Characteristics of studied membranes.

Technical data	UF membrane	NF membrane
Active layer	PES	PES
Support layer	PET	PES
MWCO (kDa)	150 kDa	1 kDa
Pore size (µm)	0,04	-
Water permeability (L/(h m^2 bar))	> 280	> 5

RESULTS AND DISCUSSION

Table 3 shows the operating conditions of both the anaerobic and subsequent aerobic treatment.

Table 3. Operating parameters under anaerobic and aerobic conditions.

Parameter	Unit	Values			
		Anaerobic trials		Aerobic trials	
		UF	NF	UF	NF
Temperature	°C	36±2	36±2	20±2	20±2
TMP	bar	0.1-0.15	0.1-0.4	0.17-0.3	0.2-0.25
pH Feed pH Effluent	---	7.0 ± 0.5 8 ± 0.5	7.0 ± 0.5 8 ± 0.5	7.0 ± 0.5 8 ± 0.5	7.0 ± 0.5 8 ± 0.5
Permeate Flux	L/(m^2 h)	7-11	1-5	10-15	2-6
HRT	h	200-350	600-1100	100-200	330-1160
OLR	(kg COD/(m^3 d))	0.5-0.8	0.15-0.4	0.04-0.15	0.007-0.025
F/M ratio	(kg COD)/(kg MLSS d)	0.04-0.06	0.01-0.03	0.01-0.02	0.001-0.002
MLSS	kg/m^3	12-13.5	11-12	~6	~6
DO	mg/L	---	---	4-6	4-6

As shown on Figure 2, the treatment under aerobic conditions improved the COD removal rate by increasing from 87% under anaerobic conditions to 97% and from 95% to almost 100% for the UF and NF membranes respectively. Red azo dyes proved being better removed under anaerobic conditions compared to the blue anthraquinone dye what is in agreement with other studies. Nevertheless the combined process allowed a complete removal of both dyes. (Figure 3). No significant fouling was observed neither for the anaerobic nor for the aerobic process.

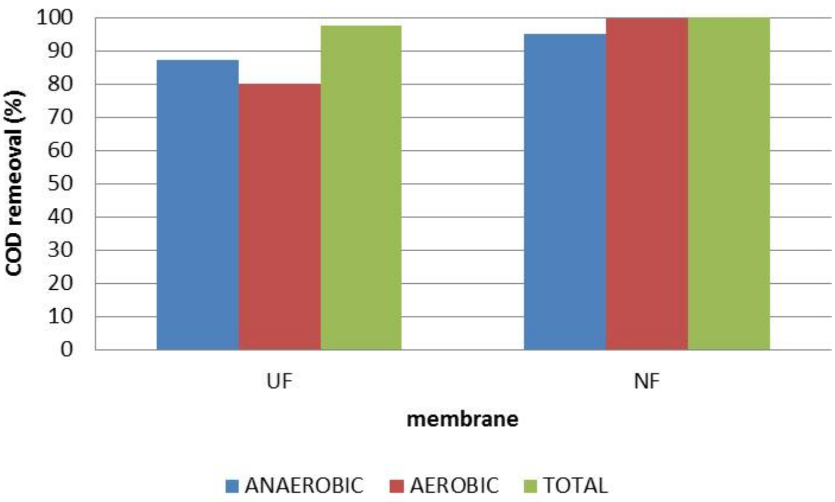

Figure 2. COD removal efficiency for the anaerobic, aerobic as well as combined process.

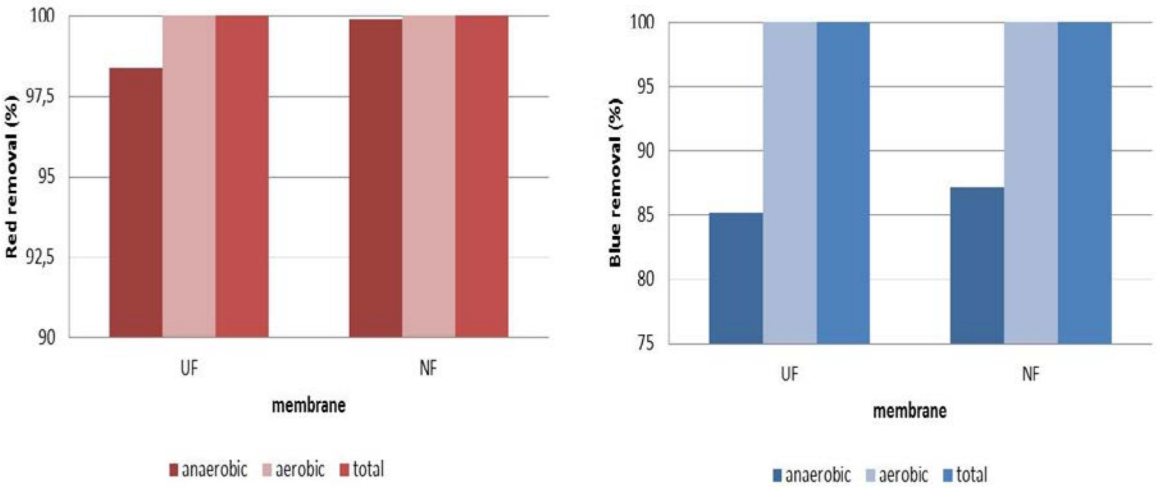

Figure 3. Colour removal efficiency for the anaerobic, aerobic and combined process.

CONCLUSION

The findings showed that for the AnMBR process the COD degradation rate depends more on the conditions of the biocenosis than on the molecular weight cut-off (MWCO) of the studied membranes (UF, NF). A high decolourisation was achieved already by the anaerobic step in particular for the azo dye what is in line with other studies. The subsequent aerobic treatment can be regarded as polishing step to eliminate remains of COD and colour (Figure 4). No significant fouling was observed neither for the anaerobic nor for the aerobic process. The results showed that wastewaters containing azo and anthraquinone dyes can be successfully treated regarding COD and colour removal by a combined anaerobic/aerobic process using UF membranes. If needed a loose NF membrane for the aerobic step can further increase the water quality regarding salt removal. Figure.4 below, shows the real samples taken from feed solution of the MTDW before, through and after the treatment, mainly the last phase under the combined conditions.

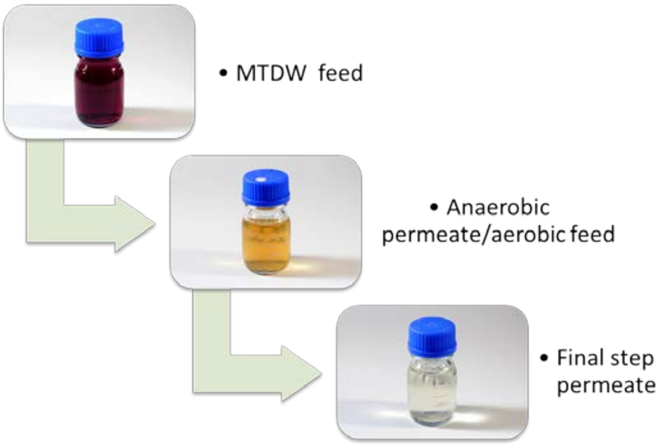

Figure 4. Samples from feed to permeate through the whole process.

REFERENCES

Hoinkis, J., Deowan, S.A., Panten, V., Figoli, A., Huang, R.R., Drioli, E. 2012 Membrane bioreactor (MBR) technology – a promising approach for industrial water reuse. Proc. Eng. 33, 234–241

Judd, S., Jefferson, B., 2003 Membranes for industrial wastewater recovery and re- use. Elsevier. Oxford

Schoeberl, P., Brik, M., Bertoni, M., Braun, R., Fuchs, W. 2005 Optimization of operational parameters for a submerged membrane bioreactor treating dye house wastewater. Sep. Purif. Technol. ,44, 61–68

Yigit, N.O., Uzal, N. Koseoglu, H., Harman, I., Yukseler, H., Yetis, U., Civelekoglu, G. &Kitis, M. 2009 Treatment of a denim producing textile industry wastewater using a pilot-scale membrane bioreactor. *Desalination*, 240,143-150

Yurtsever, A., Sahinkaya, E., Aktaßs, Ö., Uçar, D., Çınar, Ö., Wang, Z., 2015 Performances of anaerobic and aerobic membrane bioreactors for the treatment of synthetic textile wastewater. Bioresource Technology 192 , 564–573