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Research Paper

Efficient Treatment of Domestic Wastewaters by Using a Dynamic Membrane Bioreactor System

Azize Ayol *,1, Yaşar Onur Demiral 2, Sinem Güneş 2

[1] *Dokuz Eylül University, Department of Environmental Engineering, Tinaztepe Campus, 35160, Buca, Izmir, Turkey*
[2] *Dokuz Eylül University, Graduate School of Natural and Applied Sciences, Environmental Engineering, Izmir, Turkey*

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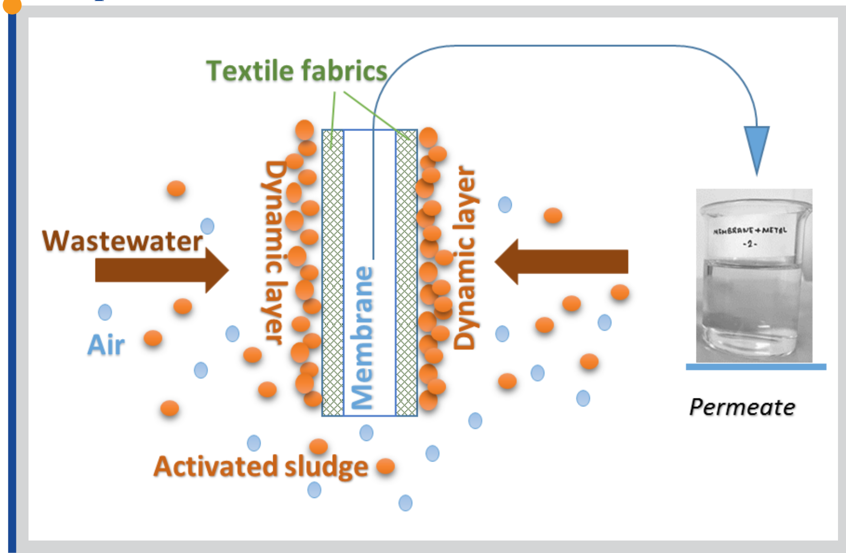
Highlights

- Two textile fabrics were evaluated as support layer to be used in dynamic MBRs.
- Both fabrics exhibited good removal performances and led to lower filtration times.
- The usage of the textile fabrics prevented the clogging of the membrane material.

Graphical abstract



Abstract

Membrane bioreactor (MBRs) technology is a crucial treatment process having enhanced solid/liquid separation in the way of biological wastewater treatment. However, clogging problem in MBRs is a critical drawback. Dynamic membrane (DM) technology has recently taking more attention to eliminate the clogging problem. DM is known as a self-forming cake layer on a support layer determining the rejection properties of the system. Recently, there is a great concern and more research need to understand and model the complex structure of DM and find proper support material. This study focused on the development of an efficient DM system with different textile fabric support materials in order to treat domestic wastewater. The applicability of two textile fabrics as cotton textile fabric (TF) and metal braided one (MBTF) as support layers with ultrafiltration membrane (UF) were investigated based on the chemical oxygen demand (COD), suspended solids (SS), specific resistance to filtration (SRF), and cake depth parameters. COD and SS removal efficiencies showed that TF support layer provided better reductions.

1. Introduction

The interest in membrane systems for wastewater treatment has been increasing during the last decades. The first because is that the membrane systems are sustainable compared with conventional treatment processes and the second because is that they allow wastewater to be reused with less energy requirement. Among the membrane systems, membrane bioreactor (MBRs) technology is accepted as crucial treatment process having enhanced solid/liquid separation being done in the way of biological wastewater treatment [1,2]. However, the clogging problem in MBRs is the critical drawback leading to the low flux, energy demand, membrane cost in terms of sustainability of the system. The concern still continues to raise in finding the effective solutions to eliminate the problem. Dynamic membrane (DM) technology has recently taking more attention for this purpose. DM is known as a self-forming cake layer consisting of flocks, microbial cells, extracellular polymeric substances (EPS), and other organic and inorganic solid particles in

* Corresponding author: azize.ayol@deu.edu.tr (A. Ayol)
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wastewater on a support layer determining the rejection properties of the system. While these materials accumulate on the support layer, they become thicker over the time and lastly form a cake layer [3,4]. The support layer is very critical that the membrane itself might no longer be required. In addition, water and/or air backwashes, can be sufficient for DM cleaning without using chemical reagents [5,6].

Some research studies focused on the modified MBRs with coarse meshes or fabrics as alternative filter materials [7]. As one of the advanced modified MBR system, the pre-coated DM is formed on the supporting membrane. Although different supporting materials including polyester mesh, polypropylene mono-mono filament woven fabrics, stainless-steel mesh, activated carbon sponge, etc. have been used, they all had varying effects on the cake formation depending on their characteristics [8]. For example, Li et al. [8] reported that the large pore size media having a larger filtration area and less filtration resistance than the small-pore mesh, it also provides higher filtration flux for same operational conditions. On the other hand, Cai et al. [9] mentioned that the large-pore size support material led to unstable effluent quality. To determine the appropriate support material, the pore size is critical for DM formation time, flux, and removal of pollutants [8].

The concern about the DM application is related to the high filtration flux via low transmembrane pressures (TMP) [10,11]. The clue affecting the investment and operational costs in this process is the support material to be used as filter clothes and meshes. Previous research studies focused on the use of low cost support layer materials, which are applicable for wastewater treatment, and also determine the characteristics of cake layer formed on supporting materials. However, there is still much more research need to understand and model the complex structure of DM layer and also find the proper support material. This study focused on the development an efficient dynamic membrane system with different textile support materials having different pore sizes in order to treat domestic wastewater. The initial research results are presented in this paper and debugged regarding the reusability of the treated effluent.

2. Material and methods

Municipal wastewater samples (WW) were taken after the grit chamber units at Manisa Wastewater Treatment Plant, Manisa-Turkey. Waste activated sludge (WAS) samples were also collected at the recycling sludge line in the plant. Both the samples were stored at 4 ºC prior to use to prevent the possible chemical reactions and microbial activity. The wastewater characteristics were first determined. Chemical oxygen demand (COD), pH, electrical conductivity (EC), total solids (TS), suspended solids (SS) parameters were analyzed according to Standard Methods [12]. Table 1 shows the characterization results of WW and WAS samples.

The textile fabrics as cotton textile fabric (TF) and metal braided one (MBTF) to be used as support layers were supplied from a textile factory located in Izmir, Turkey. TF and MBTF were produced from cotton and MBTF was woven with 50 micron stainless steel wire. Both of the weaved fabrics were developed under R&D studies. Properties of the textile fabrics were given in Table 2. For the first time, the availability of the usage of the fabrics in wastewater treatment field was tested in this study. Membrane used in the experimental studies was a PVDF ultrafiltration membrane.

A modified design of specific resistance to time to filter (SRF) test apparatus were used to determine the appropriateness of the textile fabrics. The filtration apparatus having a dead end filtration mechanism and the filter cloth –textile fabrics, membrane or the both- was set as either a filtration cloth or a support layer. Data analysis was based on several measurements. The volumes of filtered water through short depths on fabric filter cloth were plotted as a function of time. The rate of filtered water was found, as a function of total sample volume, solid content, and the specific resistance of the forming cake as described in Ayol et al. [13]. The permeate sample was also exposed to characterization studies based on the COD, SS, particle size distribution parameters. The particle size distribution analysis was done by using Malvern Mastersizer 2000 device equipped with Hydro-QM unit. The wastewater samples were used alone and as a mixture with WAS in the volume ratio as 1:1/1 and 1:½ (WAS/WW) to determine the depth of the sludge cake formed as a dynamic layer and treatment performance under different solids concentrations.

The filtration results were converted into SRF values for comparison purposes as described in Ayol and Dentel [14]. As a well-known parameter in sludge dewaterability, the SRF is derived from Darcy's law as given in elsewhere [15]. This parameter was evaluated for the determination of the appropriate support layer for DM application. The rearranged form of this equation is as follows:

Table 1
WW and WAS characterization results.

Parameter	Unit	WW	WAS
COD	mg/L	400	540
SS	mg/L	180	7890
pH	-	7.93	7.40
EC	µS/cm	1006	860

Table 2
The properties of the textile fabrics used as a support material.

	Fiber thickness (Ne)	Weft warp density (wire/cm)	Pore size (µm)
Cotton textile fabric (TF)	30x30	27x30	20
Metal braided one (MBTF)	12 for cotton	50 µm for stainless steel wire	30

$$\frac{1}{q} = A\left(\frac{dt}{dV}\right) = \left[\mu\left(SRF.\zeta_s.\omega_c + R_m\right)\right]/p \tag{1}$$

where q: flow rate per area (m³/m²s); V: filtrate volume (cm³); t: filtration time (s); A: area (cm²); p: pressure (Pa); µ: viscosity (Pa.s); SRF: specific resistance to filtration (m/kg); ζ_s: solid density; ω_c: precipitated solids' volume; and R_m: resistance of the filter media (1/m). The slope of a filtration plot gives the SRF via

$$SRF = (2pb)/\mu c \tag{2}$$

where c is the solids fraction of the samples. More information about the calculations can be found in Ayol et al. [13] and Ayol and Dentel [14].

3. Results and discussion

Figure 1 and Figure 2 present COD and SS changes under different operational conditions. The both textile fabrics exhibited good COD and SS removals. However, the treatment efficiencies of DM applications as M+TF and M+MBTF were better than those in the fabrics used alone. In the case of M+TF application, COD and SS were found lower than 5 mg/L, respectively. Cai et al. [9] reported that the effluent COD values for the 25-, 10-, and 5-µm mesh filters as 17.5, 14.5, and 16.2 mg/L, respectively and concluded that effluent COD concentrations were not affected by pore size. However, their work also indicated the possibility of lower COD values in the case of DM retaining heterotrophic biomass.

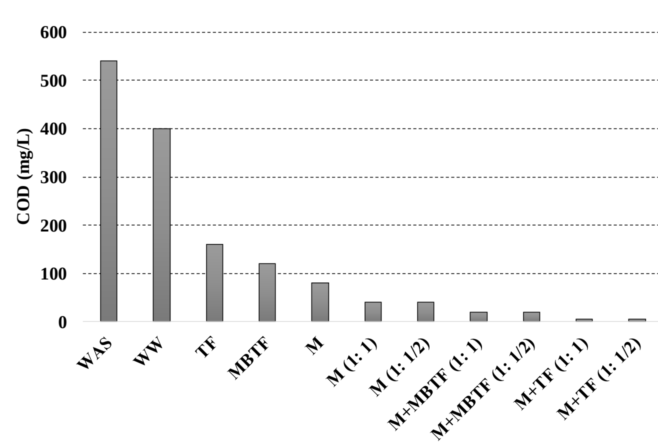

Fig. 1. The changes of COD values under different DM applications.

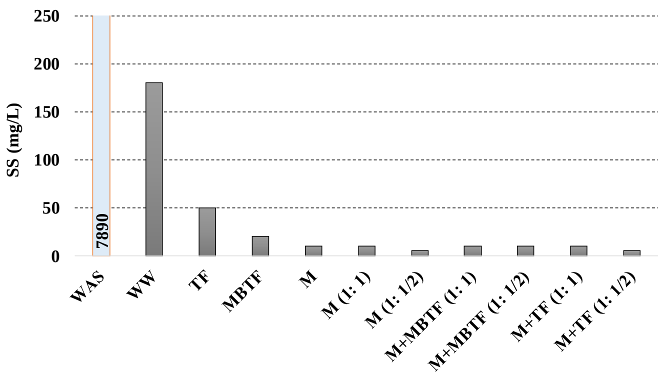

Fig. 2. The changes of SS values under different DM applications.

Particle size distribution of WAS, WW and permeate samples treated by different membrane applications was depicted in Figure 3. Volume weighted mean D [4,3] and surface weighted mean D [3,2] values were determined as 157.987 and 14.352 µm for WAS sample while they found as 94.943 µm and 46.683 µm for WW sample. Liang et al. [16] indicated that larger particles could be easily precipitated onto supporting material in a short time. The results showed that all membrane applications enhanced the quality of the permeate samples; however, the membrane supported by textile fabrics led to better quality interims of particle availability in the effluents. The permeate sample treated with M+TF (1:1) application had D [4,3] and D [3,2] as 14.016 µm and 7.577 µm, respectively, while these values were measured as 5.508 µm and 3.865 µm for the samples treated with M+TF (1:1/2). M+TF was found the best application, which is also consistent with SS results. Very clear permeate samples were obtained in all membrane applications as shown in Figure 4. The usage of the textile fabrics prevented the clogging of the membrane material and the accumulated sludge material on the fabrics created an extra layer behaving like a membrane and the filtration times were found as lower than those in the membrane used alone. The photographs of the textile fabrics and membrane after the filtration were also given in Figure 5.

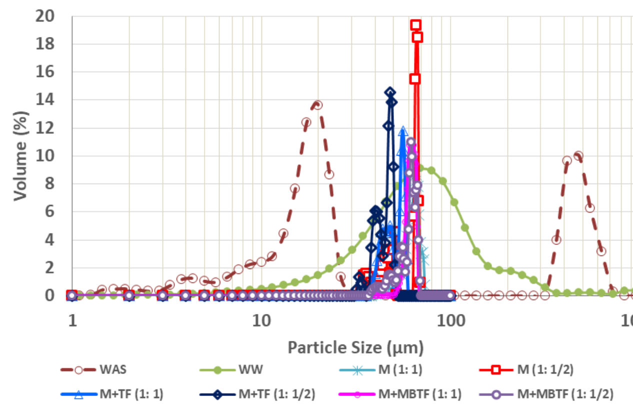

Fig. 3. Particle size distribution of WAS, WW and permeate samples treated by different membranes.

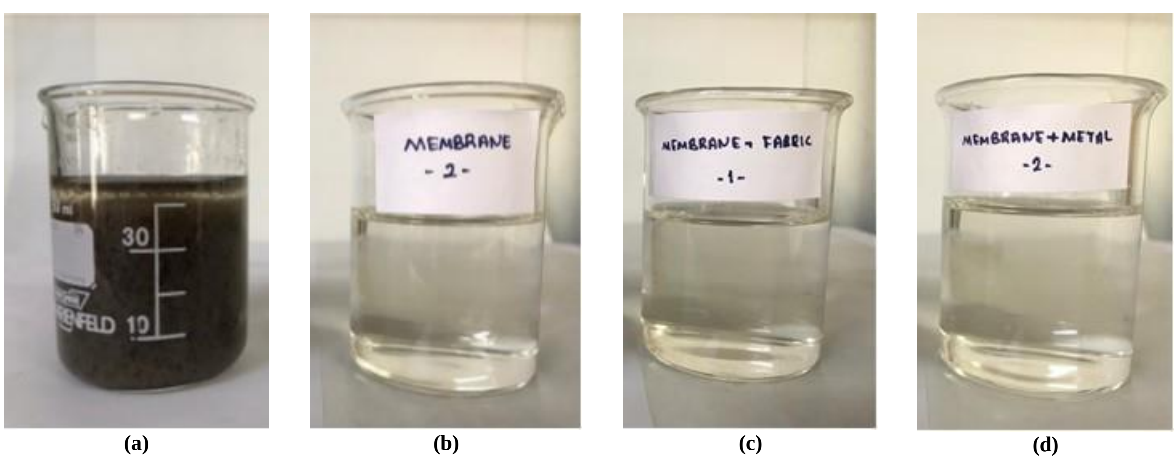

Fig. 4. The photographs of WW+WAS and permeate samples: (a) WW+WAS, (b) M treated permeate, (c) TF + M treated permeate, (d) MBTF + M treated permeate.

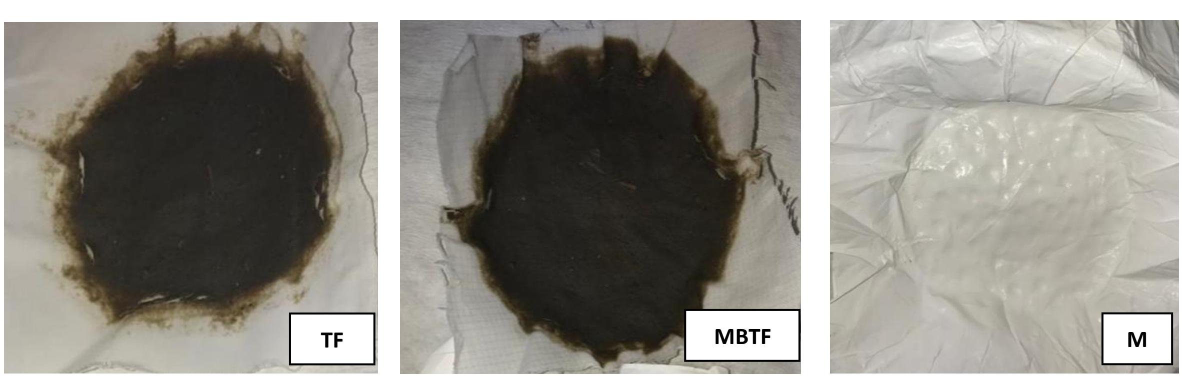

Fig. 5. The photographs of textile fabrics and membrane after filtration

To reduce the membrane clogging and provide a long term operation, dynamic membrane can be used effectively. However, the supporting layer is very important. The calculated SRF values of TF, MBTF, M, M+TF, and M+MBTF applications were found as 16.5 Tm/kg, 10.2 Tm/kg, 14.3 Tm/kg, 16.4 Tm/kg, 10.9 Tm/kg, respectively. Since TF has lower pore size than MBTF, the applications using TF material led to higher filtration resistance as reported in Li et al. [8]. The sludge cake thickness was found as 7.4 mm, 5.7 mm, 7.2 mm, 6.0 mm for TF, MBTF, M+TF, and M+MBTF applications, respectively. Ersahin et al. [17] exhibited the correlation between DM thickness and filtration resistance. The thicker cake layers had higher filtration resistance. The thickness measurements were found consistent with SRF values. The use of specific resistance to describe a filtration process is justified in theory, but was found difficult in practice as explained in Ayol and Dentel [14]. The main reason is the low solids concentration in the accumulating cake does not provide a high resistance to filtration even when the specific resistance is high. Compressibility and blinding problems should be also considered as important factors. Figure 6 shows the filtration data. The filtration took longer time in the case of membrane used alone to achieve the same sample volume as the permeate. The textile fabrics led to lower filtration times and also provided longer membrane operation.

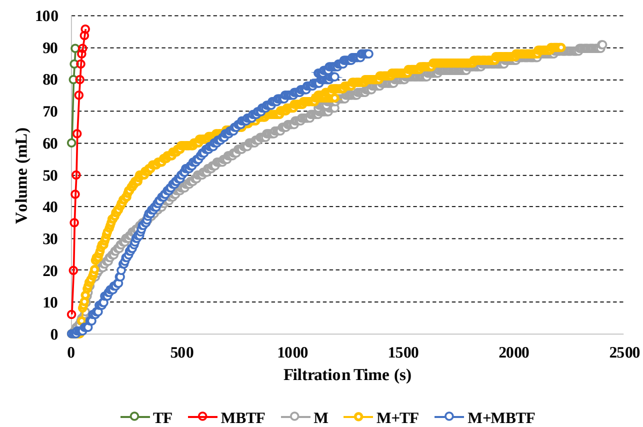

Fig. 6. Filtration volume as a function of time for WW samples treated by different membrane applications.

4. Conclusions

DMBR is considered as very effective technology in wastewater treatment field including the high organic material and suspended solids removals, excellent particle rejection performance, higher operational flux, etc. The support layer material to be used in DM is very critical in this process. As a part of a large scale research project, the potential of two textile fabric materials was evaluated for this purpose. Initial results indicated that the both materials exhibited good removal performances and lower filtration times. Regarding the COD and SS removals and higher cake thickness, TF were found more suitable for DMBR. Ongoing research is to found different metal braided textile fabrics to be applicable of DMs and operate lab-scale and pilot scale DMBR units for the optimized wastewater processing regarding the full-scale operations.

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