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Evaluation of flat sheet membrane bioreactor efficiency for municipal wastewater treatment

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ABSTRACT

Aim: In this paper, the feasibility of flat-sheet membrane bioreactor (FS-MBR) for municipal wastewater treatment was studied.
Materials and Methods: In this study, treatment of municipal wastewater in a submerged FS-MBR was investigated under different aeration time and flux. A bioreactor consist of microfiltration membrane (MF) and actual municipal wastewater as influent stream. The FS-MBR was operated during 161 days.
Results: The result showed that average removal efficiencies of chemical oxygen demand (COD), biological oxygen demand (BOD_5), total suspended solids (TSS) and volatile suspended solids (VSS) were obtained >90% and with variation of influent COD, BOD_5, TSS and VSS, the removal efficiency no significantly change. The mixed liquor-suspended solids (MLSS) and mixed liquor volatile-suspended solids (MLVSS) concentration during experiment increases from low concentration to about 7.9 and 6.5 g/L, respectively. The average of PO_4^{3+}-P, total kjeldahl nitrogen (TKN), ammonia and fecal coliform (FC) removal efficiency during the operation period was 62, 98, 70% and 8 log, respectively.
Conclusion: It is concluded that FS-MBR can be used in the large scale municipal wastewater treatment plants to improve effluent quality due to high removal of COD, BOD_5, TSS and VSS to meet effluent discharge standards.

Key words: FS-MBR, microfiltration, municipal wastewater, submerged membrane

INTRODUCTION

The available resources for potable water purpose are finite and application of wastewater provide the potential resources, so wastewater treatment and reuse is necessary. From 1970s, utilization of membrane separation processes have been developed and membrane unit used instead of the conventional secondary clarifiers in activated sludge treatment systems.[1] Membrane bioreactor (MBRs) can be broadly defined as systems integrating biological degradation of waste products with membrane filtration. They have proven quite effective in removing both organic and inorganic contaminants as well as biological entities from wastewater.[2]

The application of MBR process were progressed wastewater treatment due to reliability and simplicity. The first series of MBRs for municipal wastewater treatment in Europe were commissioned in 1998. The advantages offered by MBRs over conventional activated sludge process (ASP) include a small footprint, reduced sludge production, better control of biological

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activity, effluent that is free of bacteria and pathogens, smaller plant size, and higher organic-loading rates.[2-5] In addition, MBRs have the advantage of allowing hydraulic retention time (HRT) and solids retention time (SRT) to be independent of each other and highly efficient nutrient removal.[4,5]

The two main segment of a MBR including the activated sludge process and membrane separation process. In MBR, the microfiltration (MF) or ultrafiltration is used in order to separate MLSS from wastewater stearms microorganisms.[6,7] The reactor is operated similar to a conventional activated sludge process but no need to secondary clarification and tertiary steps like sand filtration.[6,7]

The two main MBR configurations including either submerged membranes or external circulation (sidestream configuration).[6] The submerge configuration, the membrane unit are used in immersed system in bioreactor stream flowed out to in of membrane. The submerged MBRs are usually operated at low differential pressure and in comparison to sidestream type need to less pumping and operating cost and low cleaning and high aeration and investment costs.[8]

During last decade, MBR process exceedingly were used for treatment of domestic/municipal, industrial wastewater, potable and surface water and irrigation and processing water.[9,10] In previous study, the MBR was used for treating wastewaters with flat-sheet membrane[1,11] as well as with hallow fiber.[7] In these studies, organic material removal efficiency was obtained >95%.[1,7,11]

The aim of study was to investigate of flat-sheet membrane bioreactor (FS-MBR) efficiency in treatment of actual municipal wastewater.

MATERIALS AND METHODS

This study was performed in a pilot scale FS-MBR system that was fed from a Isfahan South municipal wastewater plant (Iran) after primary sedimentation. The FS-MBR system consisted of a completely mixed aeration tank in which a bundle of flat sheet was immersed. The bioreactor was constructed of plexiglass with a working volume of 140 L and dimension of 130 × 23 × 65 cm. The membrane was made of polyethersulfone with a pore size of 0.2 μm and a filtration area of 0.5 m^2. A schematic of FS-MBR is illustrated in Figure 1.

The influent manicipal wastewater was taken from the storage reservoir and fed to the bioreactor. To achieve an aerobic condition for the normal growth of activated sludge, an diffuser aerator was employed in bioreactor which also produced stirring within the reactor. A suction pump was used to extract the filtrate water from the membrane and initially, FS-MBR was operated under aerobic conditions and no sludge inoculation. The operating conditions are summarized in Table 1.

The test methods were adapted from standard methods for the examination of water and wastewater.[12]

RESULTS

The FS-MBR system removed chemical oxygen demand (COD), biological oxygen demand (BOD_5), total suspended solids (TSS), volatile suspended solids (VSS) at a high efficiency under all operating conditions, despite the fact that various of influent wastewater quality arrived to FS-MBR system. The results of the COD, BOD_5, TSS, VSS removal efficiency during experiment are shown in Figures 2-5.

The Table 2 is summarized the variation of influent and effluent concentration and removal efficiency of total kjeldahl nitrogen (TKN), ammonia, phosphorous and FC during operation of FS-MBR.

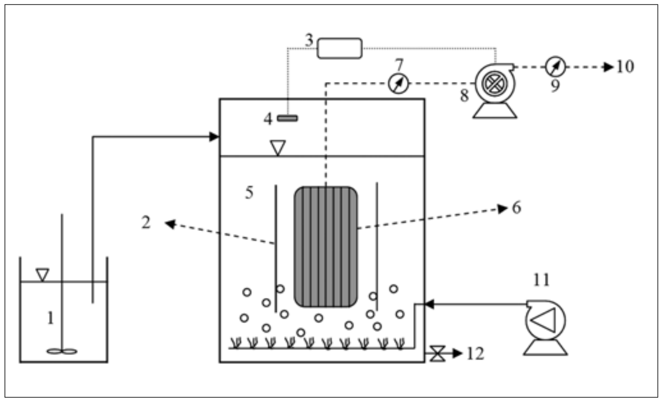

Figure 1: Exprimental set up of FS-MBR : 1) reserviour, 2) baffle plate, 3) PLC, 4) sensor, 5) bioreactor, 6) membrane module, 7) vacuum gauge, 8) suction pump, 9) flow meter, 10) permiate, 11) blower and 12) waste sludge.

Table 1: Operating conditions of the pilot scale FS-MBR

Parameter	Day		
	1-110	111-138	139-161
HRT (h)	20	16	12
SRT (d)	110	27	22
Flux (L/m².h)	7	8.8	11.7

Table 2: Effect of FS-MBR on nutrient and FC variation during experiment

Parameter	Value		
	In (mg/L)	Eff (mg/L)	R (%)
TKN	35.1 ± 3.7	10.6 ± 2.4	70.1 ± 3.9
Ammonia	33.1 ± 3.2	0.41 ± 0.2	98.8 ± 0.4
NO_3^-	0.02	8.9 ± 0.6	-
NO_2^-	0.01	0.01	-
PO_4^{3+}	8.48 ± 0.7	3.23 ± 0.6	62.1 ± 4.7
Fecal coliform (MPN/100ml)	2.1 × 10^{14}	2547	8 log

The variation of COD/BOD_5 ratio in influent wastewater and permeate are depicted in Figure 6. The average of COD/BOD_5 ratio in inlet waster and permeate was 2.1 ± 0.1 and 12.5 ± 4.1, respectively.

Figure 7 shows the increasing of MLSS and MLVSS during the 110 days of FS-MBR operation. It can be seen that during 110 days, the MLSS and MLVSS increases from low concentration to about 7.9 and 6.5 g/L, respectively.

Figure 8 portrays the trends of the suction pressure (SP) increase during the 110 days operation of FS-MBR. It can be observed that during this period, the SP increases with time as the MLSS concentration in the bioreactor increases. The initial SP and the ultimate SP of the during this experiment was about 124 and 293 m Bar, respectively.

DISCUSSION

The COD, BOD_5, TSS, VSS removal performance of the FS-MBR system

The results showed that at the three HRTs employed, the COD, BOD5, TSS, VSS removal efficiency from the influent wastewater was consistently >91% [Figure 2-5]. Initially, COD and BOB_5 removal efficiency by FS-MBR was relatively low and this fact was due to insufficient biomass growth in system. The highest removal COD and BOD_5 efficiency was obtained at 48 and 153 day, with influent of 281.3 and 256.4 mg/L, respectively; that was >99%. The influent COD and BOD_5 was fluctuated from 228 and 112 to 740 and 295 mg/L, respectively; however, the concentration of COD and BOD_5 in filtrate was maintained at a low level.

This result is in accordance with Naghizadeh *et al*. and Grelot *et al*. that reported COD removal values higher than 95%, despite large fluctuations in influent conditions.[1,13]

In all experiment, TSS and VSS concentration in filtrate is very low and the TSS and VSS removal efficiency of FS-MBR under all operating conditions was >98%. Because a MF membrane was used, the low levels of TSS and VSS was obtained. This results was confirmed by previous research.[13]

Variation of nutrient and FC removal

As it was expected, the removal efficiency of phosphorous in all operating conditions was not very high, because the system did not consist of an anerobic reactor. In MBR process that the sieving mechanisms was dominate, typically, particulate phosphorous eliminated. The average of PO_4^{3-}-P removal efficiency of the FS-MBR during the operation period was 62.1 ± 4.7%. These results were in agreement with Chae and shin.[14]

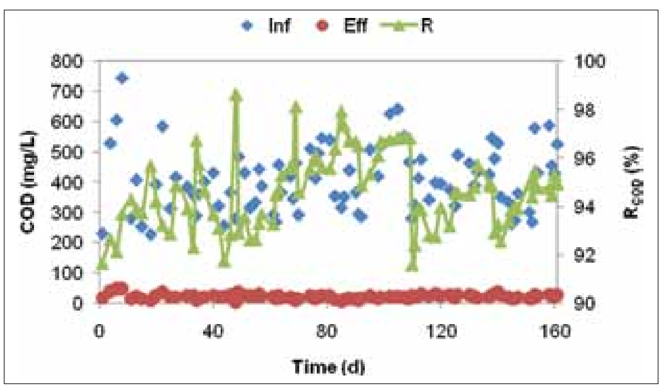

Figure 2: The variation of COD_{Inf}, COD_{Eff} and COD removal during operation

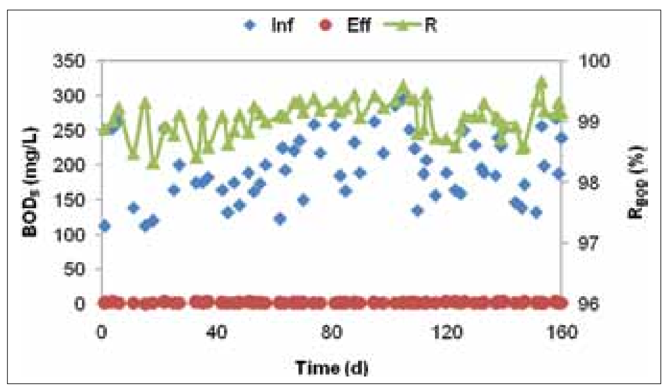

Figure 3: The profile of BOD_{Inf}, BOD_{Eff} and BOD_5 removal during operation

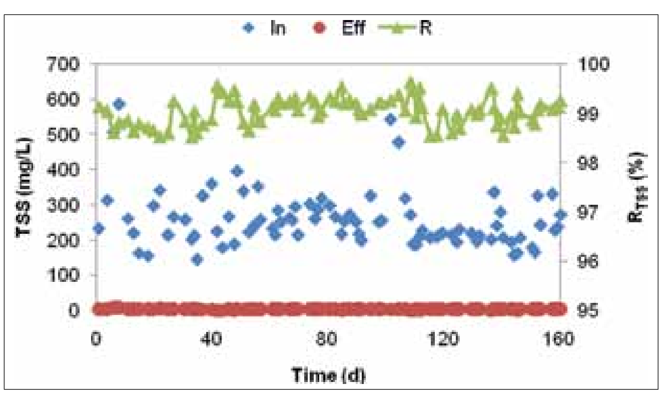

Figure 4: The variation of TSS removal efficincy during expriment

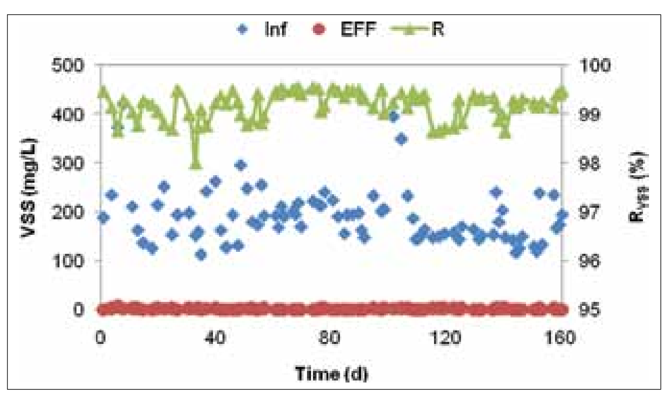

Figure 5: The VSS removal rate by FS-MBR during this study

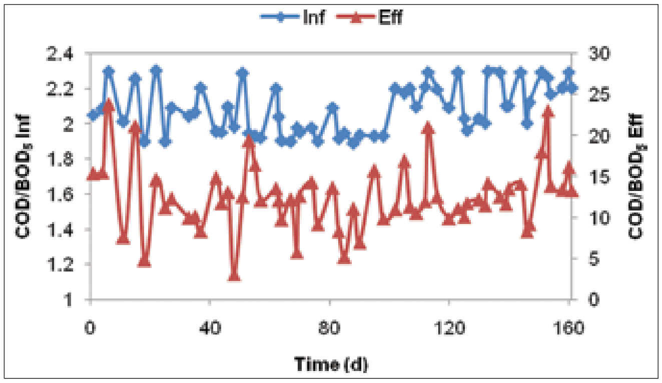

Figure 6: The flacyualtion of COD/BOD$_5$ ratio in influent and effluent

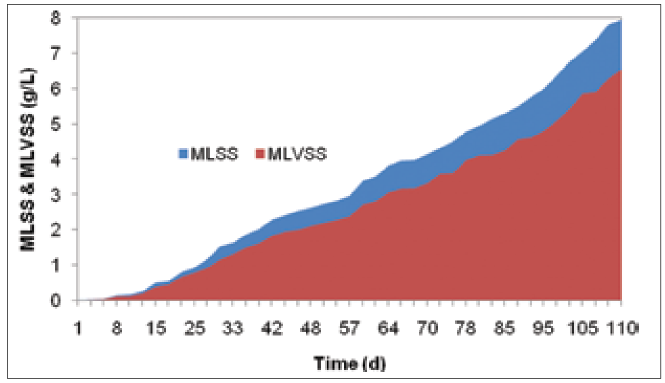

Figure 7: Profile of comulative of surplus MLSS and MLVSS during study (Maximum sludge formation was obtained in 110th day of opration)

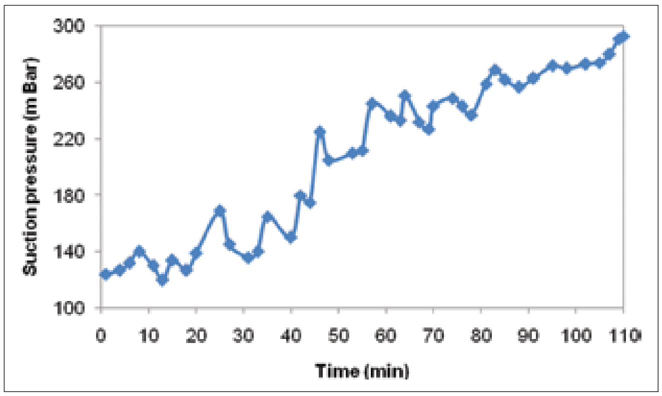

Figure 8: The variations of suction pressure of membrane module

The nitrate was present in feed wastewater at low concentration (0.01 mg/L), it was produced as a result of nitrification of NH_4-N during the oxic (aerobic) phase (8.9 mg/L) and converted to N_2 during the anoxic phase. Therefore, nitrate removal efficiency is also an important parameter for nutrient removal operations.

In this study, the ammonia removal efficiency was very high (>98%) because in aerobic condition, the ammonia was converted to nitrate during nitrification cycle. The result are in line to Blstakova *et al.*[15]

The average of FC removal in FS-MBR was 8 log and related to this fact that, the size of FC is higher than membrane porous. Grelot *et al.* mentioned similar results and reported that by application of FS-MBR filtration, total coliforms removal can achieved to 7.2 log.[1]

Effect of HRT on FS-MBR performance

The effect of HRT was minimal on organic removal and COD and BOD$_5$ removal by FS-MBR and was found to be greater than 91%, even with a short HRT. The result of this study are in line to Chang *et al.*[16] COD and BOD$_5$ removal in the bioreactor decreased slightly from 97 and 99% to 95 and 98% with fluctuation HRT from 20 to 12h, respectively.

In general, a short HRT can induce a large OLR. Thus, HRT is expected to be an important operating parameter in MBR systems, correlated not only to the treatment efficiency of the MBR system itself[17] but also to the characteristics of the biomass in the activated sludge system.[18,19]

Surplus sludge production during operation

During operation of FS-MBR, the MLSS and MLVSS content in the reactor continued to rise from low concentration to almost 7.9 and 6.5 g/L [Figure 7]. The results are well consistent with the studies conducted by Khongnakorn *et al.* and Wang *et al.*[20,21] Initially, the MLVSS/MLSS ratio was 0.78 and then gradual increase in the ratio of MLVSS/MLSS to 0.82 after 110 days of operation. The augment in the ratio of MLVSS/MLSS indicates that biological activity of the reactor may have improved over the time. The previous study reported that the variation in the MLSS content in the reactor did not exert any discernible influence on the overall biological performance of the MBR system.[22] But, Ren *et al.* reported opposite observation and mentioned that COD removal increased with increase of MLSS.[17]

At equivalent sludge residence time, the sludge production of the MBR is less than that commonly reported in the literature for conventional processes.[23,24] The low sludge production rate, or even complete stagnation of MLSS for MBRs, has been reported earlier,[25] and explained by low food to microorganism ratio, which lead to competition among the microorganisms and resulted in a reduction of sludge production. To maintain membrane permeability, the SMBR process is limited to maximum mixed liquor suspended solids (MLSS) concentrations of 10 - 20 g/L.[26]

The variations of suction pressure

The characterization of fouling during the operation of FS-MBR in the present study was performed through monitoring of suction pressure (SP) [Figure 8]. It can be observed that during operation period, the SP increases with time as the MLSS concentration in the bioreactor increases. Liu *et al.* and Hong *et al.* reported similar observation.[27,28] It was reported that membrane fouling could result in a reduction of permeate flux or an increase in SP (or TMP) depending on the operation mode used.[29] The SP, which indicates the extent of membrane fouling, was monitored at regular intervals. FS-MBR is usually operated for high concentration of sludge biomass, which could lead to membrane fouling that could decrease the flux and increase the SP.

Fouling most commonly takes place external to the membrane, forming a dynamic layer at the membrane surface. As most membrane processes operate in the cross flow mode, fouling through the formation of such a dynamic layer might be expected to reach equilibrium once the adhesive forces between the layer and the membrane substrate are balanced by the shear forces at the layer-solution interface. In practice, equilibrium is not always attained, indicating some component of the overall hydraulic resistance to be time dependent.[4] It was understood that the formation and maturation of the biofilm on the suspended carriers resulted in much less accumulation of foulants on the membrane surface.

It is concluded that FS-MBR can be used in the large scale municipal wastewater treatment plants to improve effluent quality due to high removal of COD, BOD_5, TSS and VSS to meet effluent discharge standards.

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