

Comparison of the Purifying Performances of Membrane Bioreactor Lab Scale with Activated Sludge Treatment

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Abstract: As the principal objective, this present study compares the purifying performances of the membrane bioreactor (MBR) with the conventional activated sludge used from the wastewater treatment plant of Beni Messous (Algiers) with the average characteristics in the chemical oxygen demand being 586 mg/L and 188 mg/L in the biochemical oxygen demand and 14 NTU of turbidity. The membrane bioreactor received the domestic wastewater in side stream with an ultrafiltration membrane under the following conditions: mixed liquor suspended solids concentration 4g/L; cross flow velocity $U=4\text{ m/s}$ at constant transmembrane pressure 0.8 bar. The results obtained show a better elimination of carbonaceous pollution and suspended solids (SS) for the MBR with COD final value equal to 10 mg/L and 2 mg/L in BOD_5 and 0,3 mg/L for SS. For the conventional activated sludge, we obtained a final value equal to 77 mg/L for the COD and 18 mg/L for BOD_5 and 25 mg/L for SS.

Keywords: Membrane bioreactor, activated sludge, wastewater, fouling.

1. INTRODUCTION

Membrane bioreactor (MBR) technology which combines biological-activated sludge process and membrane filtration has become more popular, abundant, and accepted in recent years for the treatment of many types of wastewater, whereas the conventional activated sludge (CAS) process cannot cope with either composition of wastewater or fluctuations of wastewater flow rate. The membrane bioreactor constitutes a physical barrier blocking the passage to the particulate organic matter similar to the inert fractions coming from the biomass. Also, the membrane bioreactors have the capacity to retain not only the bacteria resulting from the biological treatment but also the faecal coliforms, virus and other micro-organisms coming from the wastewater. This allows a total disinfection of the effluent whatever the load and the fluctuations of the affluent [1, 2]. Weak production sludge is observed with the membrane bioreactors. This can be due to the often insufficient quantity of substrate taking into account the use of great concentrations in biomass [3], with the shearing generated by the pumping which stresses the bacteria and limit thus the synthesis of new cells [4-6]. The major disadvantage of the membrane bioreactors with is the progressive reduction of the permeate flux. This decline is caused by the phenomenon of concentration polarization and by the membrane fouling. The increase in the concentration of mixed liquor affects the permeate flux conversely. Strohwald *et al.*, show that the permeate flow is linearly

connected to the concentration in biomass (between 20 and 29 g/L) with a factor of 2,66 in the membrane bioreactor with external loop with the increase in the viscosity of mixed liquor [7]. However, Shimizu *et al.*, showed that the linear relation between the concentration of the suspended solid and flux can be observed below 8g/L in the immersed membrane bioreactor, while this same relation is observed with stronger concentration in biomass in the membrane bioreactor with external loop, and a significant shear stresses generated by circulation in the membrane bioreactor with external loop [8]. Whereas, when the rate of circulation increases by 1.5 to 2.6 m/s, the flux starts to increase by 20 L/ hm^2 with 45 L/ hm^2 . It means that tangential rate can constitute a major factor controlling the flux.

We can compare the performances of the two reactors, one small scale and a large scale, and we can conclude that there are severe differences between lab scale and full scale operation presented in the Table 1.

The aim of this present work is to show the comparison between the performances of the membrane bioreactor and the activated sludge treatment used in the wastewater treatment plant.

2. MATERIAL

We considered the analysis of treated water resulting from the conventional activated sludge and the membrane bioreactor side stream with external pressure driven membrane filtration.

Presentation of the Wastewater Treatment Plant

The process of the Beni Messous municipal wastewater treatment plant (WWTP) which is located at 20 km of the Algiers west is constituted of a primary treatment and second

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Table 1. Typical Ranges of Operating Parameters and Conditions for Different Plant Sizes [9]

Parameter	Lab Scale	Pilot Plant	Full Scale
Volume	1-10 L	100-1000 L	10 m ³
Operating time	Hours- weeks	Weeks-months	Several years
Energy input	5-20 kWh/m ³	1-10 kWh/m ³	0.5-1 kWh/m ³
Feed composition	Constant	Constant./ Fluctuating	Fluctuating
Hydraulic load	Constant	Constant./ Fluctuating.	Fluctuating
Temperature	Constant	Lab: constant./field: Fluctuating	Fluctuating

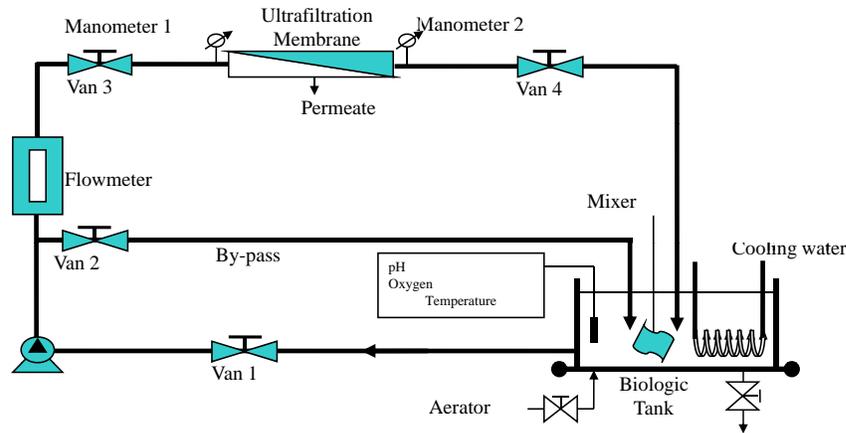


Fig. (1). Experimental Set up.

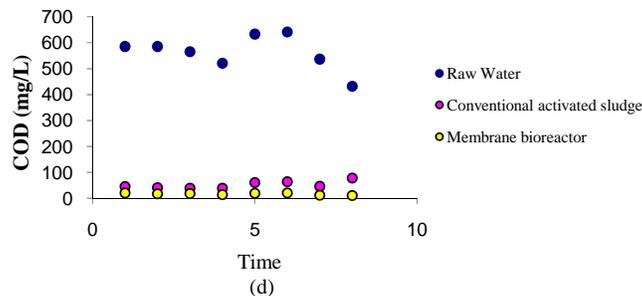


Fig. (2). COD of the raw water and treated by the conventional activated sludge and the membrane bioreactor.

dary treatment (conventional activated sludge). The treatment capacity of the WTP was about 50400 m³/d. The lab scale MBR as shown in (Fig. 1) installed at our laboratory consisted of an effective volume of 30L. An air compressor, type Resun P 1500 was fed to the bioreactor. The bioreactor is sown by activated sludge coming from the WWTP of Beni Messous (Algiers) at mixed liquor suspended solids concentrations (MLSS) equal to 4 g/L. A tubular inorganic membrane CARBOSEP M2 with cut off = 15 kg/mol was used (porous carbon support and membrane layer of ZrO₂) with an internal diameter= 6 mm, an external diameter =10 mm. The operating conditions are constant transmembrane pressure ΔP= 0,8 bar and a rate of circulation U= 4m/s. The temperature in the mixed liquor was equal to 28°C. The membrane bioreactor long term test was running for about 192 hours. The following parameters were analyzed for the raw water and treated water for the membrane bioreactor and conventional activated sludge: COD, BOD₅, suspended solids, turbidity, and pH.

Analysis Methods

Classical methods for determination of retained parameters have been used (AFNOR standard). The turbidity has been measured with the help of MERK turbidimeter 1500T which was calibrated. The pH was measured with a calibrated pH meter, HANNA type 211. The COD and BOD were measured with AFNOR methods.

RESULTS AND DISCUSSIONS

Comparison of the purifying performances of the membrane bioreactor and the conventional activated sludge

Chemical Oxygen Demand (COD)

Fig. (2) represents the results of the raw water and water treated of the COD resulting from the conventional activated sludge and the membrane bioreactor.

The membrane bioreactor gave COD removals up to 97% while the conventional activated sludge achieved removals of

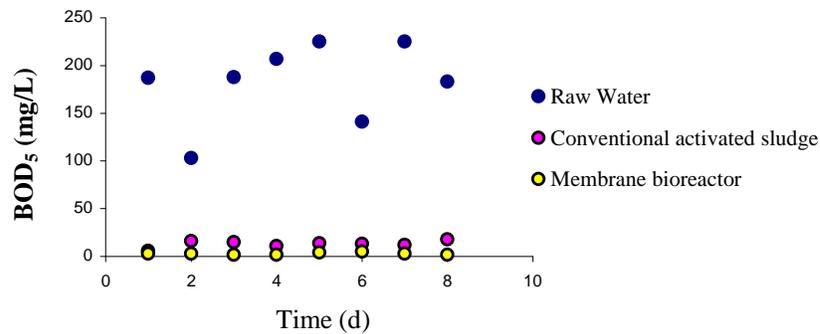


Fig. (3). BOD₅ of the raw water and treated water by the conventional activated sludge and the membrane bioreactor.

91 %. These differences in results between BA and BRM can be due to the presence of biomass, proteinic compounds or dissolved and/or particulate organic matter residues in treated water, resulting from the conventional activated sludge. On the other hand during the treatment with the MBR, the ultrafiltration membrane allowed to retain all the purifying biomass as well as all the particulate organic matter, thus only the dissolved matter which could not be degraded by the bacteria in the treated water. Gander *et al.* reported that membrane contribution to the removal of organic matter was approximately 30%, this roughly equals the insoluble fraction that was removed via active biomass [10]. Knowledge about COD removal mechanisms that occur when mixing an activated sludge with real wastewater is still scarce. The microbial response to dynamic conditions in a real wastewater treatment unit can be different from simple increase in cell number (i.e., growth of microbial population), and include other substrate-removal mechanisms like sorption, accumulation, and storage [11]. There have been several investigations on treatment efficiencies of MBR and CAS processes operating under comparable conditions that have shown significantly improved performance of an MBR in terms of COD, and SS removals. There are several factors that may contribute to the lower organic carbon content of MBR effluents as compared to CAS processes, like longer retention times, smaller floc sizes, etc. Côté *et al.* attributed the improved COD removal to the avoidance of biomass washout problems commonly encountered in activated sludge process, as well as to complete particulate retention by the membrane [12]. Membrane rejection of a significant amount of soluble organic molecules and colloids makes their removal more effective due to a higher lyses activity in the reactor induced by elevated concentrations of these compounds. Higher sludge ages that are achieved by long sludge retention time (SRT) allow more complete mineralization of biodegradable raw water organics, but also an adaptation of microorganisms to less biodegradable compounds. Therefore, biomass can acclimatize to wastewater without being restricted to fast-growing and floc-forming microorganisms. Flocs in a bioreactor were found to be smaller [13], which can explain enhanced mass transfer for both oxygen and carbon, thus enabling a higher removal rate and more adaptability to changes in the influent quality and quantity [14]. In another study, it was demonstrated that the flocs were more active and displayed greater species diversity [15]. The overall capacity of biomass to degrade different carbon substrates does not change significantly at different SRTs, which con-

firms that MBR is capable of degrading a wide variety of carbon substrates in a similar fashion.

This robustness of MBR treatment regarding turbidity and organic matter removals was confirmed in several studies [16]. Xing *et al.* recorded high treatment efficiency regardless of the absolute level of sludge concentration [17].

Biochemical Oxygen Demand (BOD₅)

The MBR appeared to be a very effective of BOD₅ removal with efficiency up to 98 % against 93 % for the conventional activated sludge represented by Fig. (3).

We also note a fluctuation in the removal efficiency of BOD₅ for the conventional activated sludge, on the other hand for the membrane bioreactor, this last remained constant during all the period of the study. There are still very satisfactory results obtained with the membrane bioreactor due to the stage of filtration.

Suspended Solids (SS)

Suspended solids can be removed by the MBR, a quasi complete elimination with 99% abatement rate of the suspended solid against an average elimination of 86 % for the conventional activated sludge represented by Fig. (4).

The capacity of the ultrafiltration membrane is to retain all the insoluble matters in water, even those of very low dimensions like the colloidal particles. Whereas for the conventional activated sludge, the settling makes it possible to eliminate only the settleable particles. The particles with low density or dimension are not precipitated. They are found consequently in the treated water.

The Turbidity

Fig. (5) showed the evolution of turbidity of the raw water and treated water by activated sludge and membrane bioreactor.

The best reduction in turbidity obtained for treated water by the membrane bioreactor, with a quasi null turbidity, and 2.77 NTU for the conventional activated sludge. This is due to a complete retention of particulate matter by the membrane, there are no suspended solids found in the MBR effluent, unlike the effluent of a conventional process. The ultrafiltration membrane can capture all suspended solids in the reactor because of its fine pore size. Therefore, non-biodegradable organic compounds are removed through filtration of particulates and discharged with the sludge.

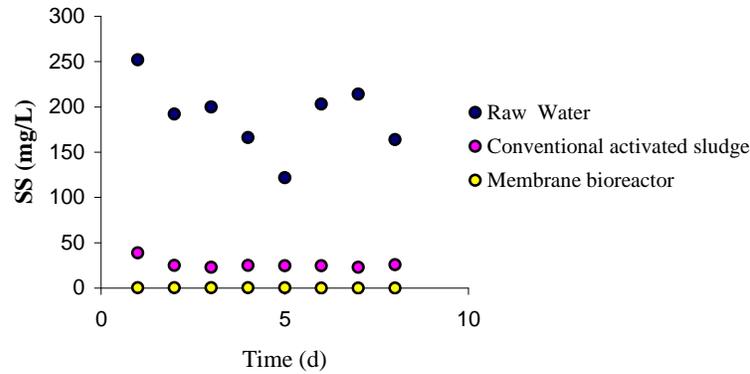


Fig. (4). Concentration in Suspended Solids of the raw water and treated water resulting from the conventional activated sludge and the membrane bioreactor.

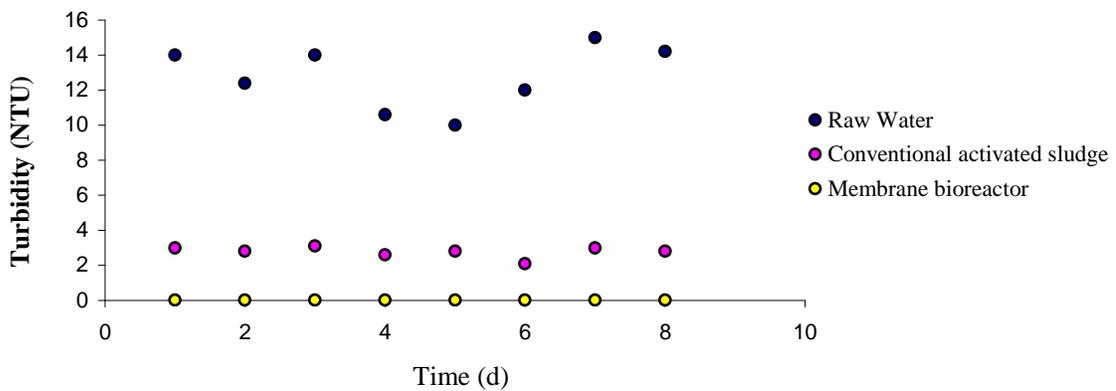


Fig. (5). Turbidity of the raw water and the water treated by two processes conventional activated sludge and membrane bioreactor.

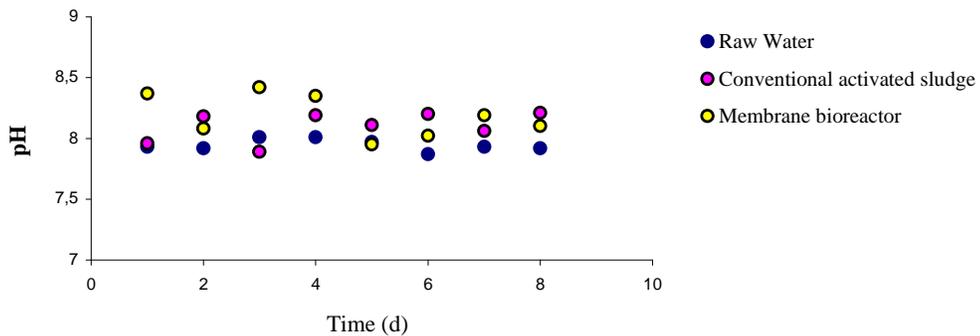


Fig. (6). pH of the raw water and treated water resulting from the two processes: activated sludge and membrane bioreactor.

pH

Fig. (6) represents the values of the pH of the raw water and treated water by the conventional activated sludge and membrane bioreactor.

The pH of the raw water was maintained at an average value of 7.82, we observe a light rise of pH of treated water 8.1 for the conventional activated sludge and 8.2 for the membrane bioreactor. These values obey the rejection standards ($6 < p H < 9$). Table 2 gives the results obtained after the treatment of domestic waste water on the one hand, with

the membrane bioreactor and on the other hand with the conventional activated sludge.

CONCLUSION

Membrane bioreactor technology is used in cases where demand on the quality of effluent exceeds the capability of the conventional activated sludge. Although the membrane bioreactor capital and operational costs exceed the costs of conventional process, it seems that the upgrade of conventional process occurs even in cases when conventional treatment works well. It can be related with increase of water

Table 2. Comparison of the Purifying Performances of the Membrane Bioreactor and the Conventional Activated Sludge

Parameters	Average Concentration of Waste Water	Average Concentration of Treated Water MBR	Average Concentration of Treated Water AS	Removal Elimination MBR (%)	Removal Elimination AS (%)
COD (mgO ₂ /L)	563±4	16±2	50±3	97 ± 5	91±4
BOD ₅ (mgO ₂ /L)	182±3	3±1	13±2	98±3	83±3
SS (mg/L)	189±3	0.2	26±8	99±4	86±2

price and need for water reuse as well as with more stringent regulations on the effluent quality. It seem clear that the use of the MBR had some important advantages like the higher removal efficiency and a higher quality effluent. Indeed, the membrane bioreactor was able to treat wastewater with high removal efficiency (about 96 %) in COD, more than 98 % of the BOD₅ like 99.9 % of SS; with the concentrations of the treated water about 10 to 20 mgO₂/L for the COD, 2 to 5 mgO₂/L for the BOD₅ and less than 0.3 mg/L for SS. Whereas the conventional activated sludge used in the WTPP of Beni Messous, was able to eliminate only 82.2 to 93 % from the COD, 90 to 96.8 % of the BOD₅ and 79.7 to 89.3 % of SS. The concentrations of treated water ranging between 38 and 77mgO₂/L for the COD, 6 and 18mgO₂/L for the BOD₅ and 22.8 and 38.9 mg SS/L. In conclusion, MBR represents an efficient and cost effective process that copes excellently with the growing needs for transforming wastewater into clean water that can be returned to the hydrological cycle without detrimental.

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