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# COMPARISON BETWEEN MBR AND MB-MBR PILOT PLANTS SUBJECT TO A GRADUAL SALINITY INCREASE: ANALYSIS OF BIOKINETIC AND FOULING BEHAVIOUR

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## ABSTRACT

Two pilot plants were investigated for the treatment of wastewater subject to a gradual increase of salinity. In particular, a membrane bioreactor (MBR) and a moving bed biofilm membrane bioreactor (MB-MBR) were studied. Carbon and ammonium removal, kinetic constants and membranes fouling rates have been assessed. Both plants showed very high efficiency in terms of carbon and ammonium removal and the gradual salinity increase led to a good acclimation of the biomass, as confirmed by the respirometric tests. Significant biofilm detachments from carriers were experienced, which contributed to increase the irreversible superficial cake deposition. However, this aspect prevented the pore fouling tendency in the membrane module of MB-MBR system. On the contrary, the MBR pilot, even showing a lower irreversible cake deposition, was characterized by a higher pore fouling tendency.

## INTRODUCTION

In the last years, MBRs have been widely used for wastewater treatment, significantly improving the efficiency of biological treatments (Meng et al., 2006), especially MBRs have also been used for the treatment of specific saline water, such as wastewater produced from shipboard activities, as an example. However, when subject to salinity, a modification of biomass characteristics may occur. This situation can play an important role in membrane fouling, which still represents one of the major drawbacks for MBRs. As a solution, in the last year has been proposed the combination of a MBR system with a biofilm process, such as a moving bed biofilm reactor (MBBR). This configuration, usually referred to as moving bed membrane bioreactor (MB-MBR) or biofilm MBR (BF-MBR), are relatively new from the point of view of kinetics and system performance especially regarding the effect of salinity owing to the very few studies developed so far (among others, Artiga et al., 2008). Bearing in mind these considerations, the aim of the paper is to present a comparison among two different systems: MBR and MB-MBR and to assess the effect of the salinity on these two systems in terms of carbon and nutrient removal, fouling behaviour as well as kinetic constants.

## MATERIALS AND METHODS

The experimental analysis were carried out on a MBR and a MB-MBR pilot plants (fig.1). Both plants were characterized by the same volume (17 L) and solid–liquid separation phase, the latter realized with an ultrafiltration (UF) hollow fiber membrane module (ZeeWeed$^{TM}$01, with specific area equal to 0.1 $m^2$ and nominal porosity of 0.04 mm). The membrane flux was kept at 15 L $m^{-2}$ $h^{-1}$. The bioreactor of MB-MBR line was filled with Kaldnes$^{TM}$ K1 carriers, with a 50% filling fraction (net surface area in the reactor of 250 $m^2$ $m^{-3}$).

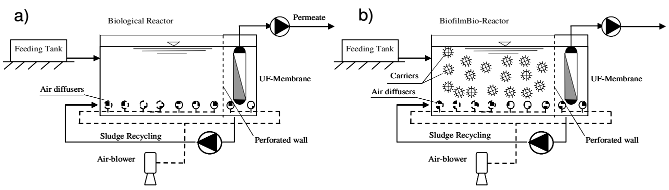


**Figure 1:** Pilot plants lay-out: (a) conventional MBR system with no carriers and (b) MB-MBR system with 50% suspended carrier

The main wastewater characteristics as well as operational parameters are summarized in Table 1,

**Table 1:** Main characteristics of the influent wastewater and operational conditions

| System / Parameter | MBR | MB-MBR |
|---|---|---|
| COD [mg $L^{-1}$] | 450 – 550 | 450 – 550 |
| $NH_4$-N [mg $L^{-1}$] | 30 – 40 | 30 – 40 |
| NaCl [mg $L^{-1}$] | 0 – 10 | 0 –10 |
| Conductivity [mS $cm^{-1}$] | 1.75 – 20.20 | 1.70 – 20.0 |
| pH [-] | 7.40 – 8.00 | 6.80 – 7.37 |
| MLSS [g TSS $L^{-1}$] | 4.10 – 7.35 | 1.35 – 4.35 |
| Biofilm [g TS $L^{-1}$] | - | 0.65 – 1.35 |
| HRT [h] | 14.00 – 16.00 | 14.20 – |
| SRT [d] | 33.50 – 36.50 | 28.00 – |

The experimental campaign was divided in five different phases, each characterized by a different NaCl dosage as reported in Table 2.

**Table 2:** Different NaCl dosage

| Phase I | Phase II | Phase III | Phase IV | Phase V |
|---|---|---|---|---|
| No salt addition | 1 gNaClL$^{-1}$ | 2.5 gNaClL$^{-1}$ | 5 gNaClL$^{-1}$ | 10 gNaClL$^{-1}$ |

During the whole period of plants operation, the influent wastewater, the mixed liquor and the effluent permeate have been sampled and analyzed for total and volatile suspended solids (TSS and VSS), chemical oxygen demand (COD), ammonium nitrogen ($NH_4$-N), nitrite nitrogen ($NO_2$-N), nitrate nitrogen ($NO_3$-N), total nitrogen ($N_{TOT}$), phosphate ($PO_4$-P) and total phosphorus ($P_{TOT}$). All analyses have been carried out according to the Standard Methods (APHA, 2005).

## RESULTS AND DISCUSSION

The two systems showed high removal efficiencies in terms of both carbon and ammonium nitrogen removal (Figure 2).

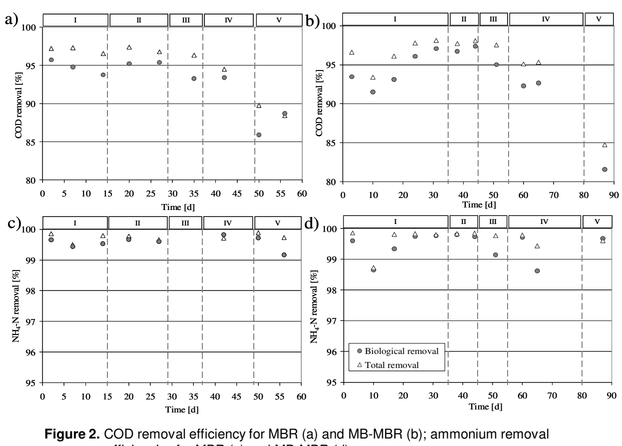


**Figure 2.** COD removal efficiency for MBR (a) and MB-MBR (b); ammonium removal efficiencies for MBR (c) and MB-MBR (d)

Concerning the COD, both plants showed high total removal efficiencies throughout the experimental campaign, with average values equal to 94 and 95% respectively for MBR and MB-MBR pilot plant (Figure 2°-2b). Nitrification activity was maintained with a gradual salinity increase, carried out with moderate salt shock steps. This result was emphasized in the MB-MBR system, since the biofilm is naturally characterized by high residence time, thus enhancing the growth of nitrifying bacteria. The results highlighted that the salinity increase by gradual steps could likely aid the acclimation of nitrifying biomass to the new environmental conditions, with no observed . significant decrease of ammonium removal.

The MB-MBR pilot plant showed a higher biomass activity, in terms of specific respiration rates, compared to the MBR plant.

It was noticed a sort of "specialization" of the two biomasses, with the suspended growth which seemed more competitive in the removal of the organic load, while the biofilm in the ammonium removal process, likely due to the high retention times characterizing the attached biomass (Table 3).

**Table 3:** Kinetic and stoichiometric parameters in the overall experimental campaign for MBR and Mb-MBR

| | MBR | MB-MBR | |
|---|---|---|---|
| | **Suspended biomass** | **Suspended biomass** | **Biofilm** |
| Heterotrophic | | | |
| $Y_H$ [mg COD $mg^{-1}$ COD] | 0.63 (± 0.09) | 0.63 (± 0.04) | 0.72 (± 0.08) |
| $Y_{STO}$ [mg COD $mg^{-1}$ COD] | 0.72 (± 0.02) | 0.69 (± 0.02) | 0.81 (± 0.1) |
| $\mu_{H,max}$ [$d^{-1}$] | 6.61 (± 2.01) | 13.3 (± 3.28) | 0.96 (± 0.6) |
| $K_S$ [mg COD $L^{-1}$] | 10.05 (± 5.1) | 4.66 (± 4.05) | 15.39 ± |
| $b_H$ [$d^{-1}$] | 0.69 (± 0.25) | 0.69 (± 0.41) | 0.58 (± 0.05) |
| $SOUR_{max}$ [mg $O_2$ $g^{-1}$TSS $h^{-1}$] | 23.43 (± 10.44) | 58.39 (± 21.91) | 17.84 (± 2.83) |
| Autotrophic | | | |
| $Y_A$ [mg COD $mg^{-1}$ N] | 0.22 (± 0.07) | 0.17 (± 0.09) | 0.25 (± 0.08) |
| $\mu_{A,max}$ [$d^{-1}$] | 0.11 (±0.04) | 0.09 ± 0.03 | 0.13 (± 0.05) |
| $K_{NH}$ [mg $NH_4$-N $L^{-1}$] | 1.57 (± 1.1) | 0.37 (± 0.22) | 0.22 (± 0.24) |
| $SOUR_{max}$ [mg $O_2$ $g^{-1}$TSS $h^{-1}$] | 2.67 (± 0.37) | 3.28 (± 1.71) | 3.51 (± 1.77) |

Higher kinetics and stoichiometric parameters in MB-MBR

Higher specific respiration rates MB-MBR

Possible "seeding" effect of nitrifiers from biofilm to the mixed liquor increasing the nitrification ability of the whole system.

Unexpected biofilm detachments were experienced in the MB-MBR pilot, which strongly affected the irreversible cake deposition. However, such a fouling mechanism contributed to increase the effect of the dynamic membrane, thus preventing the increase of the pore fouling (Figure 3). Despite in the present study the MB-MBR showed modest advantages in terms of performances respect to the MBR, such a configuration has great potentiality especially for the treatment of high strength or industrial wastewater.

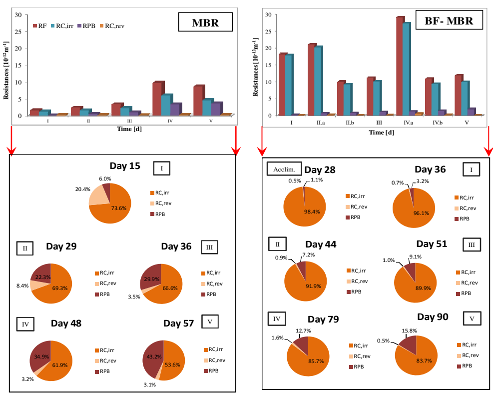


**Figure 3.** Comparison of resistances contribution for MBR and MB-MBR system

## CONCLUSIONS

The short term effects of a gradual salinity increase on a MBR and a MB-MBR pilot plants treating synthetic municipal wastewater were investigated. The two systems showed high removal efficiency in terms of both carbon and ammonium nitrogen removal. In detail, nitrification activity was maintained with a gradual salinity increase, carried out with moderate salt shock steps. This result was emphasized in the MB-MBR system, since the biofilm is naturally characterized by high residence time, thus enhancing the growth of nitrifying bacteria. Biofilm detachment phenomena were experienced in the MB-MBR plant, which strongly affected the irreversible cake deposition. However, such a fouling mechanism contributed to increase the effect of the dynamic membrane, thus preventing the increase of the pore fouling. On the other hand, the pore fouling tendency in the MBR pilot was more pronounced compared to the MB-MBR one. Finally, despite in the present study the MB-MBR showed modest advantages in terms of performances respect to the MBR, such a configuration has high potentiality especially for the treatment of high strength or industrial wastewater. Such a fact deserves to be further investigated in the future studies.

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