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Bench scale optimization of the Self Forming Dynamic MBR for wastewater treatment and effluent reuse

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INTRODUCTION

The Self-Forming Dynamic Membrane Bioreactor (SFD MBR) is a novel, sustainable and efficient approach in biological wastewater treatment.

In SFD MBR, microfiltration nets (pore size of tens of μm) are used as support for the formation of biological filtering layers resulting from the accumulation of activated sludge (i.e., the dynamic membrane, DM) (Pollice and Vergine, 2020). These systems require very low operating pressures for filtration, therefore they are suitable to gravity operation, and their productivity is maintained through periodical cleaning of the filtering supports.

The effluents of SFD MBR have similar quality of the permeates of conventional MBR (except for microbiology), with average effluent turbidity values lower than 5 NTU.

When excessive cake build-up leads to the increase of the transmembrane pressure and consequent decrease of the system's productivity, the DM has to be removed through mechanical cleaning (Pollice and Vergine, 2020). In the transient period between post-cleaning start up and the build-up of a new biological layer, effluent turbidity may have values above the average. To obtain high and stable effluent quality, a rapid formation of the DM should be promoted, and a balance between its growth and removal should be favored, ensuring the presence of a stable and unclogged biological layer over a long period.

The main results of several experiments for the operational optimization of a bench scale aerobic SFD MBR are summarized in this paper.

METHODS

Experimental systems were set up as schematized in Figure 1.

Submerged filtration modules made of nylon mesh (Nitex®, Sefar AG) were used to support the growth of the DM. During different experimental runs, the bioreactor was operated at constant flow rates and constant feed characteristics for the treatment of municipal and industrial wastewater. The SFD MBR mostly operated at very low suction pressures (below 20 mbar), which may be assimilated to gravity operation. When the DM build-up lead to periodical pressure increase, the system's productivity was restored through on-site jet rinsing of the filtering support with tap water.

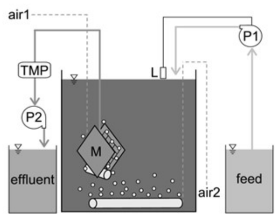

Figure 1: Bioreactor set up. P1=feed pump; L=level control connected to P1; M=filtration module; P2=effluent suction pump; TMP=manometer indicating trans-membrane pressure; air1=air pump for filter scouring; air2=air pump for mixed liquor aeration.

Continuous fine bubble air scouring of the mesh was provided in order to limit the accumulation of the cake layer on the supports and maintain a DM with a relatively constant thickness (Salerno et al., 2017).

RESULTS

Over a period of 5 years, several long-term experiments (longer than 4 times the solids retention time applied) were performed to verify the reliability of the system and study the effects of different operating conditions (mesh pore size, air scouring, solids retention time, feed) on the system's performance at the steady state. The main experimental conditions adopted are summarized in Table 1.

Table 1: Experimental conditions

Runs #	Mesh pore size (μm)	Mesh air scouring (m h^{-1})	Flux (L m^{-2} h^{-1})	Wastewater	Solids retention time (d)	Volumetric loading rate (gCOD L^{-1} d^{-1})	Duration of each run (d)
1-6	20, 50	1.3-4.2	90-95	Municipal	16	1.2	60
7	20	1.3	60-70	Municipal	15	0.9	175
8	50	1.3	60-70	Municipal	15	0.9	175
9	50	1.3	60-70	Municipal	30	1.1	140
10*	50	1.3	60-70	Municipal	30	1.1	140
11	50	1.3	60-70	Municipal	50	1.1	293
12	100	1.3	60-70	Municipal	50	1.1	260
13	50	1.3	40	Canning	25	1.2	85
14	50	1.3	40	Winery**	25	1.2	85

* Integration with biofilm reactor; ** Synthetic wastewater.

Runs 1-6 (Table 1) show that continuous air scouring was a key factor for ensuring effective operation. On the other hand, a too intense air scouring resulted in a lower quality of the effluent produced (Salerno et al., 2017).

The comparison between runs 8, 9 and 11 (Table 1) suggest that the speed of mesh clogging and the frequency of cleaning requirements were influenced by the operating conditions of the biological processes, resulting in a mesh cleaning frequency between 2 and 10 d-1.

DISCUSSION

1. High SRT values result in enhanced performance.
Higher solids retention time (SRT) values resulted in lower cleaning requirements and higher productivity. The SRT greatly affected the effluent quality, as well. Under higher SRT values (30 and 50 d) the turbidity of the SFD MBR effluent was very low and stable. This is indirectly related to the lower cleaning frequency observed at higher SRT values, which allowed the system to seldom work with a DM in its formation stage. However, this is also due to the sludge characteristics, which are positively influenced by the enhanced biomass stability related to high SRT values (Vergine et al., 2021a).

2. Air scouring optimization is required.
Continuous air scouring of the mesh was a key factor for limiting the DM growth and ensuring effective and longer operation. On the other hand, too intense air scouring resulted in lower quality of the effluent produced (Salerno et al., 2017).

3. Microfiltration mesh pore size has limited relevance.
Larger pore size resulted in lower effluent quality during the DM formation stage (first hours after cleaning) and favored the formation of preferential paths through the biological layer at high suction pressures (above 100 mbar) (Salerno et al., 2017). However, when a stable DM was achieved and under low suction pressures (steady state), the mesh pore size did not significantly affect the effluent quality. At the steady state, average effluent turbidity values in the range 1-2 NTU were obtained with all the mesh pore sizes tested (20, 50 and 100 μm) (Salerno et al., 2017, Vergine et al., 2021b).

4. Wastewater characteristics have a role.
Effluent turbidity values of SFD MBR fed with agro-industrial (canning and winery) wastewater were more variable than those observed in SFD MBR treating municipal wastewater (Vergine et al., 2020).

5. Recent developments.
A novel approach towards DM formation and maintenance is being tested. Instead of aiming at the conservation of a relatively constant cake layer, a regular renewal of the DM is promoted. Temporized actions for the automated removal of the DM through e.g., backwash or local turbulence (large bubbles, air mass load) favor the periodic DM replacement. This allows for more limited on-site mesh cleaning requirements, resulting in reduced needs of human interventions and thus making the whole process more sustainable. According to the first results, the average effluent quality is not affected.

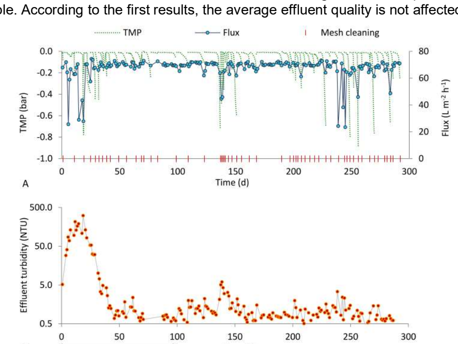

Figure 2: Example dataset of an experimental run of the bench scale SFD MBR. In diagram A) the TMP is consistently within 0.2 bar; In diagram B) the turbidity is consistently below 5 NTU (Vergine et al., 2021b).

CONCLUSIONS

Results of several long-term experiments show that the SFD MBR can produce a very good quality effluent, with a relatively low capital cost and low energy and maintenance required.

This makes the SFD MBR a sustainable alternative to conventional MBR for wastewater reclamation and effluent reuse also in decentralized installations. In particular, the limited energy and manpower requirements allow for SFD MBR applications in remote areas, where power supply may be provided through photovoltaic systems.

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