Dynamic membrane submerged in granular sludge coupled with a pilot-scale UASB reactor for municipal wastewater treatment

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Highlights:

- **The system operated for 71 days with intercalated cleanings at a flux of 100 L/m^{2}h.**
- **UASB and dynamic membrane immersed in granular sludge achieved high removal efficiencies.**
- **The permeate obtained complies with current Mexican regulations, but disinfection must be added.**

Keywords: Dynamic membrane; anaerobic granular sludge; pilot-scale

INTRODUCTION

Membrane fouling during wastewater treatment results from the deposition and accumulation of foulants (colloids, organic, inorganic, or bio-foulants) inside the pores and on the surface of the membrane. These materials affect the operability of the process due to a decrease in permeate production, which leads to an increase in the operation and maintenance costs. The drawbacks of conventional membranes (microfiltration and ultrafiltration types) have led to the concept of dynamic membranes, attracting the attention of various research groups, since they may provide permeate quality at a reduced capital and operational costs (Noyola *et al.*, 2019).

The dynamic membrane is a biofilm formed over a low-cost macroporous support (20-200 µm), such as a textile fiber or metal mesh, which acts as an active filter that improves solid-liquid separation (Batista *et al.*, 2020), achieving effluent quality nearly comparable to that obtained with microfiltration membranes. Due to the characteristics of the material, high permeate fluxes can be achieved at low transmembrane pressures (Mohan & Nagalakshmi, 2020), which increases the productivity of the system and at the same time reduces the energy requirement. Despite its advantages, this technology relies on biofilm for filtration, so adequate biofilm formation is needed.

This study aimed to assess the feasibility of using a pilot scale UASB reactor coupled with a dynamic membrane for municipal wastewater treatment control, based on the improved performance of a dynamic membrane immersed in granular anaerobic sludge.

METHODOLOGY

A pilot-scale UASB reactor of 0.7 m^3 fed with wastewater from Ciudad Universitaria, Mexico City was coupled to an external chamber (0.6 m^3) with two double-side flat sheet modules with a total filtration area of 1 m^2, using a support textile of woven polyamide with a pore size of 50 µm. The flux was fixed at 100 Lm^{-2} h^{-1} using a peristaltic pump; transmembrane pressure (TMP) was measured on-line by the water column difference between the water surface and a piezometer located at the output of the permeate (maximum value 9 kPa), using a pressure sensor (Wika, Germany). Permeate turbidity was monitored with an on-line turbidimeter (Hach TU5300 sc, USA). A Raspberry Pi 4 mini-PC was used as data logger. Total suspended solids (TSS), total and soluble chemical oxygen demand (COD) were among the parameters used to monitor the quality produced.

240 L of granular anaerobic sludge taken from a real-scale UASB reactor with a particle size distribution of 60% bigger than 1.2 mm and 40% in a range of 0.6 to 1.2 mm was added to the chamber with an average total solid of 31.5±6 gL-1 with 84% volatile fraction. A fouling control method was applied when 7.5 kPa was reached, consisting of 10 min of backwash followed by 50 min of sludge bed washout.

RESULTS AND DISCUSSION

As shown in Figure 1, the total operating time was 71 days, the first 44 days without interruption. The first cleaning was performed when a TMP of 7.5 kPa was reached. After this cleaning, it was possible to operate for another 19 days; however, the rate of increase of TMP was greater, requiring a second cleaning flush on day 63. In this occasion, the initial TMP of 3 kPa was not achieved, and a value of 4.6 kPa was obtained. This may be due to an accumulation of material strongly adhered to the fabric that could not be removed by backwashing, or to the presence of suspended solids retained by the sludge bed that were not completely removed by the upflow washout.

It is important to note that the experiment was stopped on day 71 because the university went on vacation, which changed the influent characteristics due to the decrease in campus occupancy. When the run was stopped, there was a TMP of 6.5 kPa and a turbidity of 10 NTU, indicating that the dynamic membrane was not completely plugged and could have possibly operated for a longer period. The average turbidity during the entire filtration run was always below 15 NTU, with an average of 7 ± 2 NTU (Figure 1).

Figure 1. Evolution of TMP and turbidity profile during the filtration run.

Figure 2 shows the average values of TSS, total and soluble COD at the three sampling points, as well as the corresponding removal percentages (UASB, membrane module and entire system). As can be seen, a total removal of more than 62% was obtained for the three parameters, being higher for TSS (83%) as expected. The integration of the granular anaerobic sludge bed with the dynamic membrane was able to retain the fine particles that were washed out of the UASB reactor. As for the total and soluble COD, a significant decrease was observed from the influent of the UASB reactor to the permeate. The total removal percentages (influent - permeate) were 77% for total COD and 62% for soluble COD. This effluent meets the criteria for TSS, total and soluble COD established in Mexican standards NOM-003-SEMARNAT-1997 and NOM-001-SEMARNAT-2021 for water reuse and for discharge into water bodies and infiltration, respectively.

It is important to point out that the filtration chamber achieves an additional soluble COD removal of 12% on average, which proves the metabolic activity of the sludge inside the chamber and its contribution to reduce the concentration of this parameter without an additional energy cost.

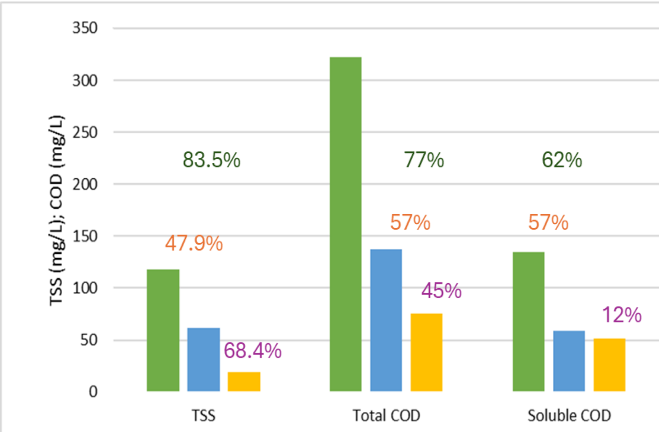

Figure 2. Quality parameters. The blue color shows the removal percentage in the UASB reactor, the yellow color shows the value obtained by the filtration module and the green one the removal percentage of the entire system.

CONCLUSIONS

The UASB reactor coupled to dynamic membranes submerged in granular anaerobic sludge produced a permeate that complies with the Mexican water reuse regulations for TSS and COD; however, a disinfection method should be added to eliminate microbiological contaminants that cannot be removed with dynamic membranes.

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