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Reduction of energy demand for UF cross-flow membranes in MBR by sponge ball cleaning

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Abstract. Sponge ball cleaning can generate an abrasion effect, which leads to an attractive increasing in both permeate flux and membrane rejection. The aim of this study was to investigate the influence of the daily sponge ball cleaning (SBC) on the performance of different UF cross-flow membrane modules integrated with a bioreactor. Two 1”-membrane modules and one 1/2”-membrane module were tested. The parameters measured and controlled are temperature, pH, viscosity, particle size, dissolved organic carbon (DOC), total suspended solids (TSS), and permeate flux. The permeate flux could be improved by 60%, for some modules, after 11 days of daily sponge ball cleaning at a transmembrane pressure of 350 kPa and a flow velocity of 4 m/s. Rejection values of all tested modules were improved by 10%. The highest permeate flux of 195 L/m².h was achieved using a 1”-membrane module with the aid of its negatively charged membrane material and the daily sponge ball cleaning. In addition, the enhancement in the permeate flux caused by daily sponge ball cleaning improved the energy specific demand for all tested modules. The negatively charged membrane showed the lowest energy specific demand of 1.31 kWh/m^3 in combination with the highest flux, which is a very competitive result.

Keywords: energy specific demand; flux; rejection; sponge ball cleaning; UF cross-flow membrane

1. Introduction

Membrane fouling is still a main obstacle in membrane bioreactor (MBR) technology used in wastewater treatment. According to the wastewater characteristics, it leads gradually to either rapid or slow decreasing in permeability. The negative effect of the fouling can be traditionally minimized by two arrangements. The first one is optimizing the key process parameters such as transmembrane pressure and flow velocity. The other one is the periodical membrane cleaning (Baker 2012). The nature of fouling layer plays an important role for choosing the cleaning methods. Three main types of fouling (biofouling, organic, and colloidal fouling) are typically observed in UF membranes used in MBR. The cleaning of fouled membranes can be achieved by either chemical washing or mechanical cleaning (Judd and Judd 2011). Chemical washing is conventionally implemented to improve the membrane permeability through known chemicals (alkali, acids, and detergents), and facilities (Cui and Muralidhara 2010). However, for many reasons chemical washing is neither economic nor eco-friendly. Chemicals required for membrane washing are expensive and they need to be transported and stored, which is place-limited in some sectors (e.g., cruise ships). Furthermore, additional line of membranes is needed during the maintenance or wash cycle. Chemical washing agents are aging the membranes and in some special cases can even damage the membranes in short period (Baker 2012). All these factors in addition to the need to treat the discharged cleaning solutions increase the cost of membrane cleaning and consequently the total cost of wastewater treatment with MBR (Jiang *et al*. 2017).

Actually, the fouling layer can also be removed from the membrane surface by physical cleaning methods (flushing/rinsing, backwashing, air sparging, sponge balls, etc.) according to Arimi *et al*. (2016). Although sponge ball cleaning (SBC) is one of those attractive and promising alternatives in the field of mechanical membrane cleaning, just few studies were conducted up to now. This is attributable to some pessimist expectations sued for the disability of SBC to remove the internal fouling in the membrane pores as Wang *et al*. (2014) reported. Furthermore, others predicted a limited application for SBC because of the control complexity of the cleaning process. They also expected that the membrane material could be damaged in case of high content of solid particles in wastewater, as particles may deposit between the ball and membrane surface during the SBC and could injure the membrane material (Cui and Muralidhara 2010).

On the other side, some important practical results were published and spotted the efficiency of this technique in membrane cleaning. Periodical SBC effectively improved for example, the permeate flux of MF cross-flow tubular

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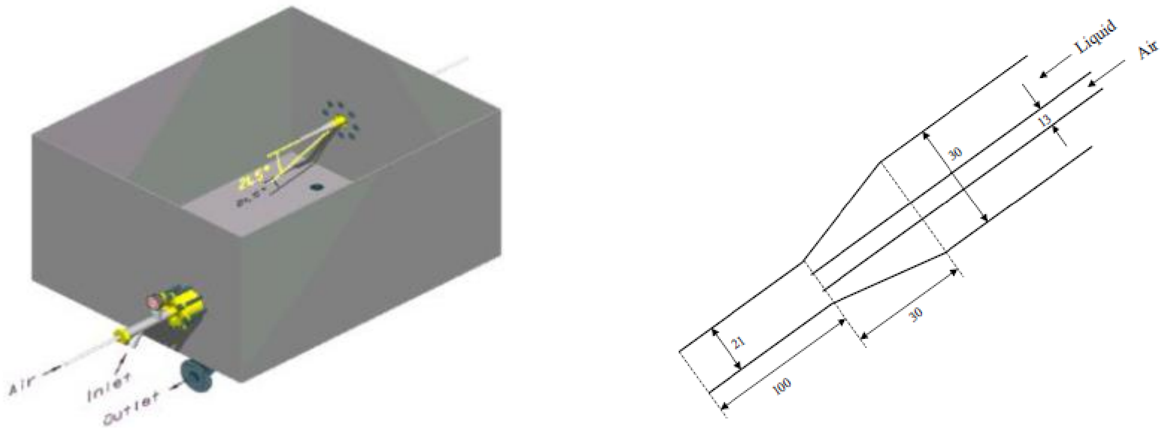

(a) Horizontal jet reactor (b) Air-liquid jet (dimensions in mm)

Fig. 1 Design of both horizontal jet reactor and its air-liquid jet

Table 1 Properties of the tested KOCH membranes

Membrane module	5-HFP-276-FVO	5-HFM-251-FVO	5-HFM-300-UEO
Membrane material	PVDF (-)*	PVDF	PVDF
Cut-off, kDa	100	250	250
Membrane area, m²	0.1	0.1	0.3
Module length, m	1.5	1.5	1.5
Module diameter, mm	42	42	42
Membrane tubes number	1	1	7
Tube diameter, mm	25,4	25,4	12,7
Prue water flux	573	411	330

*Polyvinylidene fluoride (PVDF) as membrane material of this module is negatively charged

membranes used in a drinking water preparation at different transmembrane pressures and flow velocities as Psoch and Schiewer (2006) stated. They agree with Al-amoudi and Lovitt (2007) that the simplicity of SBC allows to use it manually or automatically. Such findings encourage and support the need to better investigate SBC, which promises a simple method membrane cleaning. It can reduce the high energy demand of cross-flow membranes (Maaz *et al*. 2019) integrated with wastewater treatment bioreactors.

In this work, the mechanical abrasion influence of SBC on the membrane permeability was investigated with three different UF cross-flow membranes. They were integrated with an activated sludge bioreactor used to treat synthetic wastewater. The membranes were used to separate activated sludge after wastewater treatment and generate pure water as permeate. The study aimed to spot how far the daily SBC can raise permeate flux and how far the specific energy demand of membranes can be accordingly reduced. The influence of the daily SBC was promoted by setting up high transmembrane pressure and high cross-flow velocity.

2. Material and methodology

2.1 Horizontal jet reactor

The bench-scale plant used in this work consisted of a bioreactor combined with different cross-flow tubular UF modules. The reactor tank had a length and width of 1.24 m and 1 m respectively. The height of liquid in the reactor was 0.5 m and its total volume was 620 L. The reactor was divided equally into two zones with air-liquid jets installed opposite in the fronts (Fig. 1(a)). The recycled liquid is pumped from the bottom of the tank to the air-liquid jets where air was added. Flowrate of liquid and air through each jet were 1.5 and 2 m³/h respectively. This reactor will be abbreviated in this work as HJR (Horizontal Jet Reactor).

The air-liquid jets for this reactor were designed according to Fig. 1(b) with the air tube surrounded by the liquid tube resulting in a very effective disintegration of the air to small bubbles and thus a high mass transfer area. The momentum forced the bubbles against their rising velocity to the bottom of the reactor and prevented settling of the biomass. The jet had been located at approx. 2/3 of the liquid height up from the bottom and directed towards the bottom edge of the reactor with an inclination angle of 21.5 degrees versus the horizon. As the liquid, in the recent study, was an activated sludge medium, the mass transfer rate of the soluble pollutants from the liquid phase to the suspended fine particulates of biomass was highly improved. The transfer rate of oxygen gas from the bubbles of supplied air to the liquid phase and finally to the biomass particulates was consequently also enhanced.

Three different cross-flow tubular modules of UF membranes were used to separate biomass from activated sludge. The tested membranes (5-HFP-276-FVO, 5-HFM-251-FVO, and 5-HFM-300-UEO) were donated from KOCH Membrane Systems GmbH, Germany and abbreviated in this study as M276, M251, and M300 respectively. The properties of these membranes are shown in Table 1.

The sponge balls used for mechanical cleaning of the mentioned tubular cross-flow membrane modules were donated from Taprogge Gesellschaft mbH (Wetter, Germany). The Modell G160 of cleaning balls (Fig. 2) was recommended by the Taprogge relating to its softness that suited to remove bio-fouling from tube surfaces. A single ball with diameter of 27 mm was used to clean the 1”-

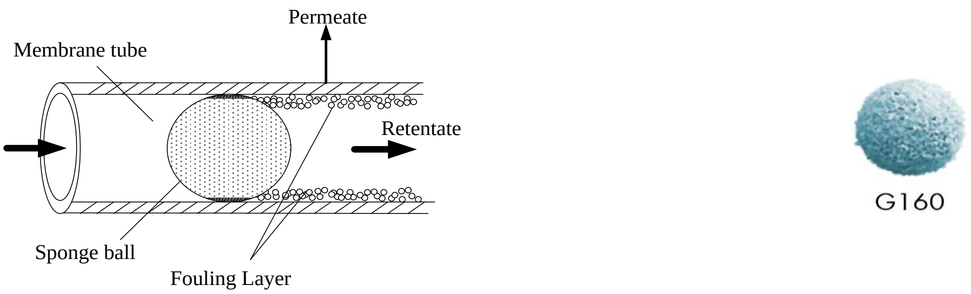

Fig. 2 Sponge ball cleaning under the force of cross flow

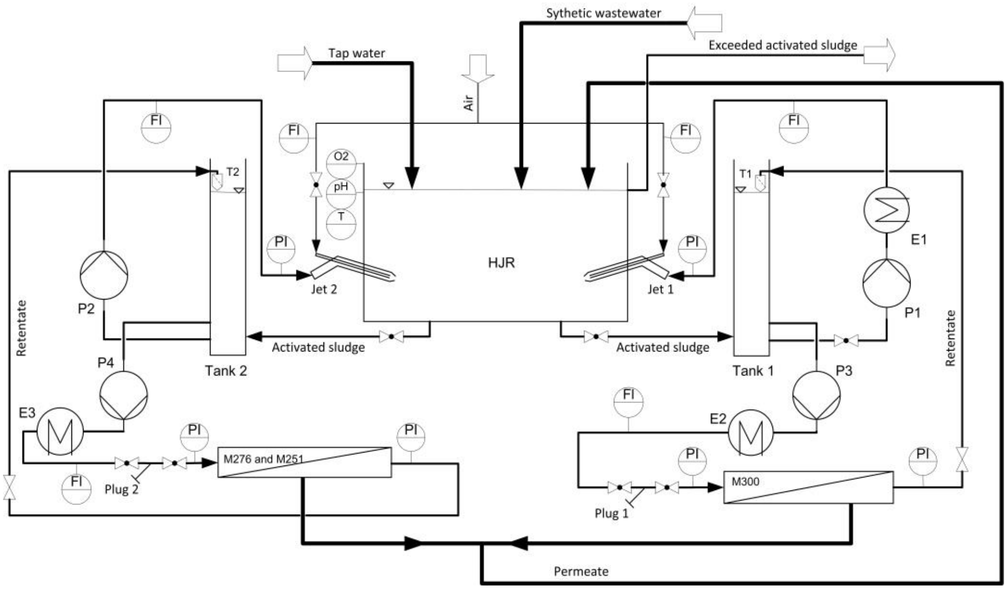

Fig. 3 Process flow sheet of HJR integrated with UF tubular membrane modules

membrane modules M251 and M276, while 14 small balls with 13 mm diameter were used together for the cleaning of the 1/2”-membrane module M300. 14 balls were chosen to increase the probability that each of the 7 tubes of the M300 module is cleaned by one pass. The diameter of the sponge balls was greater than the diameter of the membrane tubes. This arrangement enabled each sponge ball to press at the membrane surface during its crossing the whole length of the membrane tube under the force of cross-flow (Fig. 2). The abrasion effect of the sponge ball will shear off the fouling layer from membrane surface.

2.2 Experimental setup

The schematic diagram of the bench-scale plant is shown in Fig. 3. The 620 L bioreactor (HJR) was connected with two other tanks (1, 2), which had with the pipes a volume of 125 L. Both bioreactor and tanks were filled with activated sludge. The pumps (P1, P2) transported the medium with a flowrate of 1.5 m³/h from tanks (1, 2) in combination with an air flowrate of 2 m³/h through the dual air-liquid jets (1, 2) in a closed cycle. The temperature of the medium in the pilot plant was maintained at 25°C using

The flowrate of activated sludge medium through the tested membranes (M251, M276, and M300) was controlled using adjustable speed motor pumps (P3, P4). The permeate was generated under the applied transmembrane pressure and measured every day by hand. The concentrate returned in a closed cycle to the tanks (1, 2). For mechanical cleaning, the pumps (P3, P4) were turned off and the sponge balls were inserted by hand in the main pipe via drain plugs (1, 2) in front of the membrane modules. The sponge balls were forced to pass through the membranes under the force of cross flow after switching on the pumps (P3, P4) again. The sponge balls were caught by screen traps (T1, T2). This mechanical cleaning was repeated several times. Digital flowmeters were used to measure flowrate through the dual air-liquid jets and the tested membrane modules. Manometers measured the pressure at the input as well as the output of each membrane module and the pressure at the input of each jet.

2.3 Experimental procedure

The activated sludge, collected from a municipal wastewater treatment plant in Germany, was used to start up the HJR. The activated sludge medium was fed during the experiments by a synthetic wastewater (see Table 2).

A period of six days was necessary for activated sludge in bioreactor to adapt to this synthetic wastewater. Activated sludge parameters, shown in Table 3, were controlled and maintained constant during the experiments.

Table 2 Characteristics of synthetic wastewater*

Component	Value
Glucose, g/L	125
Molasses (liquid), g/L	178
$CO(NH_2)_2$, mg/L	277
$MgSO_4.7H_2O$, mg/L	100
$CaCl_2$, mg/L	7.5
KH_2PO_4, mg/L	53
K_2HPO_4, mg/L	107

*DOC of the synthetic wastewater is 55,000- 75,000 mg/L

The specific energy demand EC was calculated in kWh/m³ according to Eq. (1).

$$E_C = (Q_P * P_{in} + Q_F * \Delta P)/Q_P \quad (1)$$

where Q_P represents the permeate flowrate (m³/s), QF the feed flowrate (m³/s), P_{in} the input pressure (kPa) and ΔP the pressure drop (kPa) for each module.

Each experiment was conducted over 11 days with daily SBC and repeated in the absence of daily SBC. Samples of permeate, activated sludge, and synthetic wastewater feed were daily collected and immediately analyzed. DOC was analyzed for all three samples whereas viscosity, particle size, and TSS were analyzed only for the activated sludge samples. Temperature and pH of the medium in bioreactor (HJR) were measured in situ.

2.4. Analysis

2.4.1 DOC

The dissolved organic carbon (DOC) was measured using the analyzer TOCOR 5000 (Shimadzu, Germany) according to DIN 38 409-H3. The membrane rejection was calculated by Eq. (2) according to DOC values.

$$R = ((DOC_{AS} - DOC_P) * 100)/DOC_{AS} \quad (2)$$

where DOC_{AS} represents the concentration of dissolved organic carbon in activated sludge in reactor (mg/L) and DOC_P its concentration in permeate (mg/L).

2.4.2 MLSS

Mixed liquor suspended solid (MLSS) of activated sludge was determined in g/L according to DIN 38 414-S2.

2.4.3 Physical parameters

The pH was measured using pH 353 MultiCal device (WTW, Germany), while pH 530 OXI device (WTW, Germany) was used for monitoring the temperature and dissolved oxygen in the reactor. Manometers (WIKA, Switzerland) and flowmeters (Krohne, Germany) were used to monitor both pressure and flowrate, respectively.

3. Results

3.1 Optimal number of sponge balls crossings

Table 3 Operating parameters

Parameters	Value
Organic loading, $kg_{DOC}/m^3.d$	2
Sludge loading, $kg_{DOC}/kg_{MLSS}.d$	0.4-0.5
Sludge age, h	143
MLSS, g/L	4-5
Viscosity, mPa.s	2
Particle size, µm	4-5
Temperature, °C	25
pH	6.5-7.0
Feed flow velocity, m/s	4
TMP, bar	350
Pressure drop in M251 and M276, bar	0.12
Pressure drop in M300, bar	0.3

Before applying this procedure, the modules were chemically cleaned in a stepwise with acid and basic solutions in addition to chemical agents from Koch membrane system GmbH because the modules were fouled during previous operating. This step helped to increase the initial flux value relatively. After chemical cleaning, the modules were fed with activated sludge again under the constant conditions (Table 3). The initial flux value of each tested membrane was different as presented in Fig. 4 despite the same applied operating conditions. The mechanical cleaning with sponge balls was repeated six times to investigate the flux improvement after each sponge ball crossing. The flux was directly measured after each crossing of the sponge balls along the membrane module and the results were graphically presented (Fig. 4).

The highest flux value, 168 $L/m^2.h$, was observed using the 1”-module M276 as its membrane material PVDF is modified (negatively charged), which weakened the growth of the fouling layer and improved its permeability. This influence of such modified materials on the membrane flux was reported by some researchers as Shi *et al.* (2014) and Esfandian *et al.* (2016). They found that flux can be dramatically improved by treating membrane material with electro-coat paint for example, which increases the mutual repulsion between the retained molecules and membrane surface and decreases consequently the fouling. On the other hand, the non-modified membrane material of the 1”-module M251 showed only 104 $L/m^2.h$. The seven membrane element tubes of the 1/2”-module M300 contain membranes with the same non-modified material (PVDF) like M251. The diameter for each single tube is 12.7 mm in comparison to 25.4 mm for the other two 1”-modules (Table 1). Therefore, the Reynolds number (Re) in case of M300 is reduced to the half (Re ≈ 25500 for M300) in contrast to the other two 1”-membrane modules (Re ≈ 55000). This increased the thickness of the fouling layer on the membrane surface of M300 which reduced the flux to 70 $L/m^2.h$. It was proven in other studies that high shear rates generated at membrane surfaces shear off deposited material and thus reduce the hydraulic resistance of the fouling layer Albert *et al.* (2016), Krzeminski *et al.* (2017).

As shown in Fig. 4, the flux values of all membranes

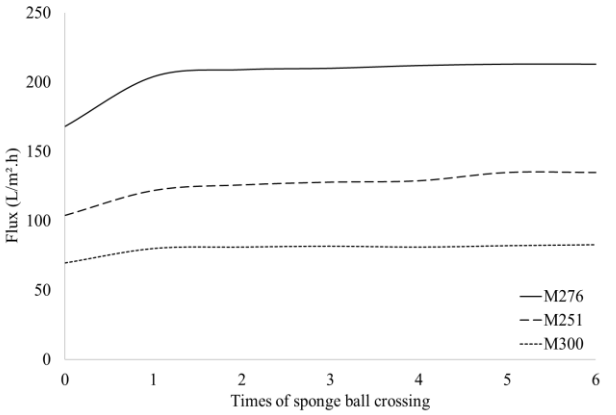

Fig. 4 Flux of different UF cross-flow membranes as a function to the number of sponge ball sequential crossings

were improved by repeating the sponge balls crossing. After the 3rd crossing, the flux remained almost constant, where the flux values of the membrane modules M276, M251, M300 increased around 20%, 19% and 14% respectively. Conclusively, just three-repeated crossings of the sponge balls were daily applied for all three types of modules in all following experiments in the present work.

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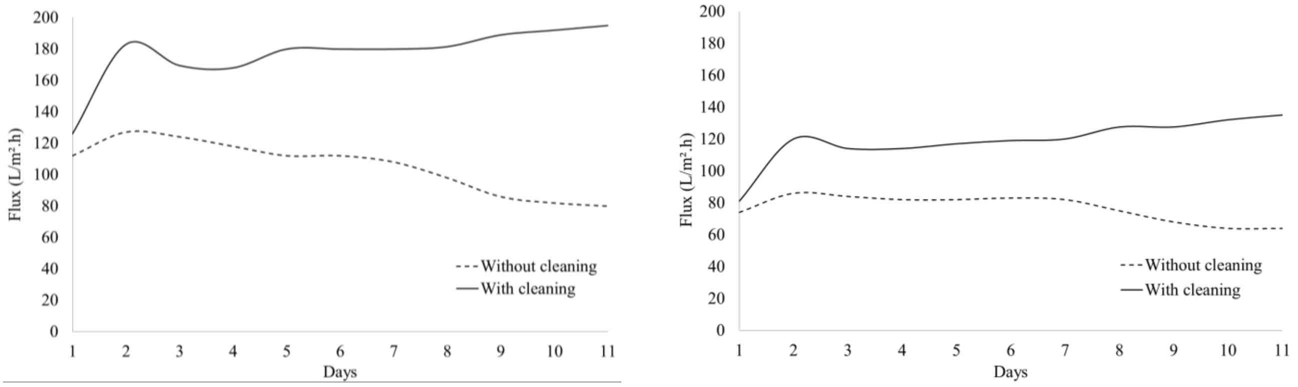
3.2 Flux

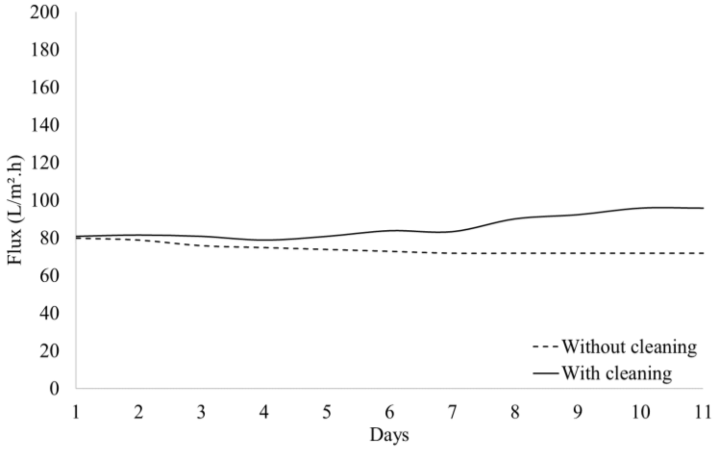
The experiments were carried out over 11 days to study the performance of the three different UF cross-flow membranes under the same operating conditions (Table 3) with the daily SBC at flow velocity of 4 m/s and a transmembrane pressure of 350 kPa. The flux values were daily measured approx. 24 h after the SBC. To show the influence of the daily SBC, the experiments was repeated for each module without daily SBC under the same conditions and period. Fig. 5(a)-5(c) show remarkable flux increases for all membranes by the daily SBC.

Fig. 5(a) shows the flux values of the module M276 with and without daily SBC as a function to the experimental time. The permeate flux at the beginning of the experiments was almost the same with and without the daily SBC. However, the module M276 showed a strong increase of the flux during the first days due to the daily SBC. The highest flux value reached 195 L/m².h after 11 days. This is an increase of approx. 60% in contrast to the same module without cleaning which showed a flux



(a) 1”-membrane Module M276

(b) 1”-membrane Module M251



(c) 1/2”-membrane Module M300

Fig. 5 Influence of SBC on the flux of UF cross-flow membranes at 350 kPa and 4 m/s

Table 4 DOC concentration in both reactor and permeate (With and without SBC)

	DOC, ppm		
Without SBC	Reactor		588 ± 49
	Permeate	M300	285± 18
		M251	236 ± 18
		M276	236 ± 18
With SBC	Reactor		581 ± 72
	Permeate	M300	246 ± 49
		M251	166 ± 27
		M276	190 ± 38

decrease to 80 L/m^2.h after 11 days.

Similar results have been achieved for the 1”-module M251. The flux increased up to 135 L/m².h by the daily SBC at the last experimental day (Fig. 5(b)). Conversely, the permeate flux declined without daily SBC over the experimental days to the value 64 L/m².h. It means, the daily SBC could improve the permeate flux by approx. 53% under the same conditions. In both cases, with or without SBC, the permeate flux of M251 was lower than that of M276. Those two UF 1”-membrane modules have identical properties except the surface charge and cut-off of membrane material. As mentioned previously, the PVDF membrane surface for M276 was negatively charged. The surface charge of this membrane increases the mutual electrostatic repulsion between the like-charged activated sludge flocs, charged negatively with Zeta potential ranging from -6 to -12 mV (Bennoilt and Schuster 2001), and membrane surface. These phenomenon decreases the growth of the fouling layer on the membrane surface (Zhu and Jassby 2019). This reduces the fouling filtration resistance and increases accordingly the permeate flux. Additionally, this influence of that electrostatic repulsion eases the function of SBC to remove fouling layer, as its binding with the membrane surface is already weak (Guo *et al*. 2018). As mentioned, such flux increasing using modified hydrophobic polymeric membrane materials was stated by other researchers (Urbanowska and Kabsch-Korbutowicz 2016), who modified PVDF with electro-coat paint to assist wetting, decrease fouling, and improve cleaning.

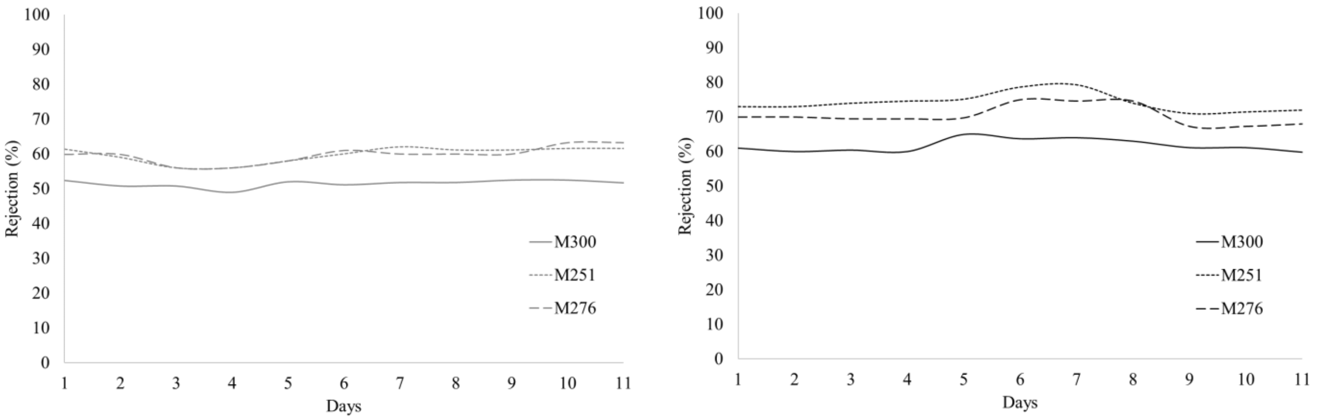
The lowest permeate flux was showed by the module M300. In both cases, presence and absence of daily SBC, the performance was lower than that for the other modules (M276 and M251) as shown in Fig. 5(c). Nevertheless, the positive influence of the daily SBC on M300 appeared as a gradual flux increasing within the experimental time. The flux value increased up to 96 L/m².h on the 11th day due to that daily SBC, whereas the absence of SBC caused a flux dropping to the value 72 L/m².h. The flux increase caused by the daily SBC (26%) is the smallest improvement in comparison to 60% for M276 and 53% for M251. It is attributable to the higher thickness of the fouling layer built due to the lower turbulence in the membrane tubes of M300 (Re≈25,500) versus that in the other two modules (Re≈55,000). This observation agrees with that found and interpreted by Ansari *et al*. (2018). Therefore, the removal of fouling layer by SBC was more difficult for the multi-tubes module (M300) and the permeability improvement was further limited. Definitely, the enhancement of permeate flux gained by the daily SBC leads to an incredible energy saving, which will be still explained in this work.

3.3 Rejection

All tested membranes could reject organic molecules to some extent. DOC values of the permeate as well as of the activated sludge medium were daily monitored. Table 4 shows these mean values in each experiment during the 11 days.

The absence of daily SBC leads to a long-term and stable polarization equilibrium at the membrane surface, which enhances the growth of the fouling layer and increases the concentration of soluble molecules near the membrane surface, where they are adsorbed during the process. Furthermore, soluble molecules pass through the membrane pores, where they are attached within as (Lin, *et al*. 2014) explained. This phenomenon is expected with the current UF-membranes. According to Clarke (2003), molasses matrix encloses high content of soluble sugars such as sucrose (30-40%, 342 Da), glucose (4-9%, 180 Da), fructose (5-12%, 180 Da), which increase the concentration of soluble molecules in activated sludge as Zhang, *et al*. (2017) also observed. As a result, the soluble molecules in molasses beside the pure glucose (s. Table 3) used to prepare synthetic wastewater can easily pass through membrane pores because of their little sizes compared to the much higher nominal pore diameter of the UF-membranes used in this work (100 kDa for M251/M300 and 250 kDa for M276). The attached soluble molecules in membrane pores lead to relative pores constriction, which mainly controls the membrane rejection independent of membrane cut-off and MLSS concentration according to Jeon, *et al*. (2016). Both modules M276 and M251 confirm this fact, as they showed almost identical membrane rejection values of approx. 60% (Fig. 6(a)) even though the cut-off is different (100 vs. 250 kD respectively). The mean value of M300 rejection (52%) was 10% lower than that of M251 despite the identical cut-off value. All those findings demonstrate that the rejection of organic molecules is really influenced by the pore constriction more than by the membrane cut-off. In case of M300, the lower turbulence accounts for a fouling growth on the membrane surface with higher fraction of macromolecules building and consequently less selective fouling layer, whereby the soluble molecules layer can easily get permeated causing a lower rejection as Amy and Cho (1999) explicated.

By the daily SBC, the rejection of all tested modules unexpected increased about 10% (Fig. 6(b)). Rejection values were 71%, 74%, and 62% for M276, M251, and M300 respectively. Indeed, the reverse case of those findings were expected, because the bare membrane and the restricted pore size in addition to the surface fouling layer (without daily SBC) must have higher rejection. Our hypothesis for those observations is that the presence of SBC will shear off the fouling layer and largely release the membrane surface and even in its pores to adsorb high



(a) Without daily SBC (b) With daily SBC

Fig. 6 Membrane rejection for the UF cross-flow membranes at TMP=350 kPa & u=4 m/s

quantity of soluble molecules. Consequently, just small quantity of that molecules penetrates through membrane pores with permeate leading to a higher rejection. This hypothesis agrees with the observations of Enfrin *et al*. (2020). They stated that more nanoparticles were getting adsorbed within the pores and onto the surface of the membrane causing high rejection, when the membrane surface was still clean (at the first hours of filtration). With growing fouling layer more nanoparticles (smaller than the pore size) cannot be more retained and can get permeated through the pores reducing the rejection. In plain terms, the cleaner the membrane surface is, the better is the membrane flux and the higher is its rejection.

Such positive effect of SBC on membrane rejection was observed and investigated by Hashino *et al*. (2011) with backwashing, who could improve both permeability and rejection of membrane material with rough gear-shaped structure. This improvement of membrane performance was also achieved by application of other techniques such as electrically-enhanced MBR (Bani-Melhem and Elektorowicz (2011), Hasan *et al*. (2014), Hosseinzadeh *et al*. (2015)), Anoxic/Oxic MBR (Khan *et al*. 2013), and Cross-flow micellar-enhanced UF membranes (Huang *et al*. 2012). All these techniques decreased the fouling on membrane surface and accordingly the thickness of the fouling layer, where the membrane performance (flux and rejection) could be effectively improved. Moreover, it is also important to mention that the noticeable stability of membrane flux and rejection within the experiments time, shown in Fig. 5 and 6, spells that the membrane material was not damaged by the SBC. This finding is related to the use of synthetic wastewater with very low inorganic content, which lets damaging of membrane material with inorganic particles (e.g., sand) improbable. Accordingly, it is recommended to investigate this aspect with other kinds of wastewater containing high inorganic content.

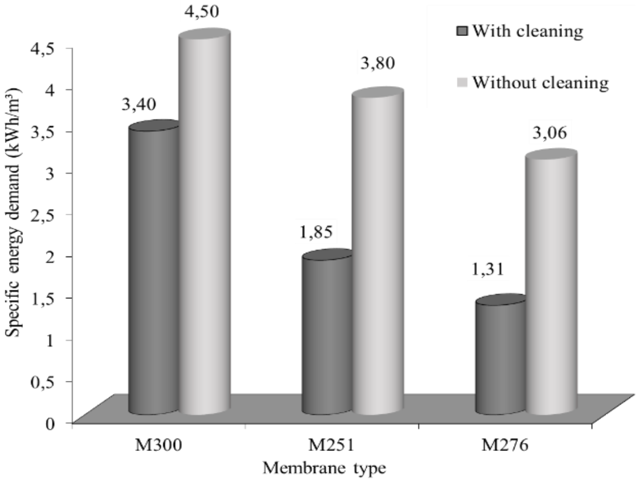


Fig. 7 Energy saving for tested UF cross-flow membranes

3.4 Specific energy demand

The specific energy demand (SED) for each membrane was calculated according to Eq. (1) and depending on flux values reached after 11 experiment days, where flux and SED are inversely proportioned. SED values with and without SED are graphically represented in Fig. 7. According to this figure, M276 showed the lowest SED (1.3 kWh/m^3) by means of the daily SBC, as its flux was the highest (see Fig. 7). In the absence of SBC, SED value of this membrane increased to 3.1 kWh/m^3. It means, the SED saving achieved by SBC for M276 was 57%. As showed in Fig. 5(a)-5(c), the flux of M251 is lower than that of M276 under the same operating conditions. For this reason, M251 had a higher SED with (1.85 kWh/m^3) and without (3.8 kWh/m^3) the daily SBC. SBC could show a considerable SED saving (51%) with this membrane, which was relatively close to that of M276 (57%). As M300 had always the lowest flux of the three membranes, its SED values either in the presence (3.4 kWh/m^3) or in the absence (4.5 kWh/m^3) of SBC were consequently the highest. The SED saving caused by SBC was 24% for this membrane. This low value is solely attached to the low flux, which caused by the thick fouling layer built under the lower turbulence prevailing in the seven tubes of this membrane.

The most attractive performance was observed using M276 module with only 1.31 kWh/m^3, which is an attractive result for cross-flow UF tubular membrane used in MBR systems. Furthermore, it is supposed to be lower for the big full-scale MBR plants (Krzeminski *et al*. 2012).

4. Conclusions

Removing the fouling layer is still a niche investigation issue to improve the membrane performance integrated with wastewater treatment bioreactors and decline the energic demand of the membrane filtration process. The daily SBC is an attractive method for membrane cleaning, which can perform this target at low costs.

In this work, SBC is successfully investigated to mechanically clean three different UF cross-flow tubular membranes connected with a membrane bioreactor used for synthetic wastewater treatment. Furthermore, SBC shows negatively remarkable influence on the membrane materials. The highest improvement is observed with the 1”-membrane module M276, which possesses a negatively charged material. By implementation of the daily SBC, the permeate flux of this membrane increases up to the value of 195 L/m².h after 11 operation days and achieves high DOC rejection (70%). Consequently, the specific energy demand is reduced 57% to meet the value 1.3 kWh per 1 m^3 of permeate. Daily SBC improves the permeate flux and the membrane rejection of the other two membranes as well but on different levels. By means of this technique, the flux of M251 increases to 135 L/m².h (at a rejection of 70%), which enables a SED saving of 51%. For M300, the lower turbulence limits the positive influence of the daily SBC, where its flux increases to only 96 L/m².h achieving a SED saving of 24% at a rejection value of 60%. Regarding that ability of SBC to effectively reduce energy demand of the whole membrane filtration process without damaging the membrane material, it is recommended to use it as periodical membrane cleaning. At the same time, it is far important to continuously monitor the secureness of membrane material through the manner of flux and rejection.

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