Petrochemical wastewater treatment and reuse by MBR: A pilot study for ethylene oxide/ethylene glycol and olefin units

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Abstract
This study aims to investigate the technical feasibility of employing membrane bioreactor (MBR) as a practical approach for ethylene oxide/ethylene glycol (EO/EG) and olefin units wastewater treatment in a petrochemical complex. EO/EG unit wastewater mainly contains ethylene glycol and acetaldehyde and olefin unit wastewater includes benzene and ethyl benzene, with COD concentration of 1900 ± 900 mg/L and 900 ± 300 mg/L, respectively. Experimental studies of MBR pilot plants with volume of 2.5 m³ were carried out during 6 months in different HRTs and various mixed ratios of EO/EG to olefin unit wastewater. Results revealed that using MBR, COD removal efficiency of 97.5% is accomplished in HRT of 13.5 h for EO/EG and 85% in HRT of 18 h for olefin wastewater. For the mixed ratio of 2/1 and in HRT of 18 and 24 h, COD removal efficiency of 93.5% and 96% was achieved, respectively. Membrane fouling was analyzed at different MLSS concentrations. The results at optimum MLSS of 8 g/L revealed that fouling resistance is mainly due to the membrane pore blocking, and cake and gel resistances contribute less to membrane fouling. Results indicated that MBR is a promising technology for treatment of high fluctuation toxic components in petrochemical wastewater.

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Introduction
Increasing demand of water for industrial use and exhaustible water resources has brought up the issue of wastewater treatment and reuse for industrial applications in Middle East [1]. The special economic zone of Imam Khomeini port petrochemical complex in Iran also faces this challenge. Marun petrochemical complex as one of major companies in this zone contains various units including EO/EG, olefin and light and heavy polyethylene. This company has attempted to provide a part of the required water through treatment of wastewater by a feasible technology.

Marun petrochemical complex wastewater mostly deals with the wastewater of EO/EG and olefin units. EO/EG unit wastewater is produced with a flow rate of 200 m³/h. COD concentration of EO/EG unit wastewater is 1000 to 2800 mg/L and has high fluctuation due to operational changes. COD concentration of the wastewater is mostly due to the presence of ethylene glycol, yet it contains acetaldehyde and formaldehyde.

Ethylene glycol is a readily biodegradable compound with a half-life of approximately 3–3.5 days which can be removed from wastewater by activated sludge process [2–4]. Although most of aerobic microorganisms in common activated sludge systems are capable of treating light ethylene glycol, presence of aldehydes in concentrations of higher than 100 ppm would affect the activity of aerobic and anaerobic microorganisms in activated sludge negatively [5,6]. Different concentrations of acetaldehyde in wastewater with a COD of 1000 to 3000 ppm can be treated using highly-concentrated activated sludge with MLSS concentration of 4000 to 12,000 mg/L in a membrane bioreactor [7]. The olefin unit wastewater, with a flow rate of 100 m³/h, has a COD concentration of 600 to 1200 mg/L after passing through an oil-water separator. Olefin unit wastewater with a COD/BOD ratio of four contains phenol, benzene, toluene, ethyl benzene, xylene, and poly-aromatic hydrocarbons (PAHs). Phenol, BTEX and PAHs are considered as hazardous contaminants in wastewater as they interrupt treatment process. This is due to the fact that they can only be removed by some microorganisms in activated sludge such
al. [8,9]. Different studies have shown that a mixture of activated sludge microorganisms can be used in MBR for treatment of olefin unit wastewater [7,10]. However, different methods are suggested for the treatment of petrochemical industry wastewater and suitable methods are determined by considering wastewater characteristics, degree of contamination and financial aspect [11].

Membrane bioreactor (MBR) is one of the most promising technologies for wastewater treatment and water reuse [12]. MBR is a combination of activated sludge process and membrane technology and is widely used for wastewater treatment. High mixed liquor suspended solids (MLSS) concentration in this technology has made it a suitable choice for treatment of highly toxic wastewater such as petrochemical wastewater [13]. In addition to decelerating bacteria growth rate and decreasing production of excess sludge, high SRT in MBR leads to growth of sludge age which in turn improves MBR ability to tolerate toxic components [14,15]. In addition to the above-mentioned advantages, less required space and high-quality effluent have made MBR a promising technology for industrial wastewater treatment and reuse [16,17]. Also growth in design and application of MBR indicate its development for wastewater treatment purposes [18]. But MBR has also disadvantages such as membrane fouling [19], biological foaming [20] and high cost of investment [21]. It should be mentioned that MBRs with microfiltration membrane for water reuse, have noticeable amount of aerobic bacteria and collophages which made ultrafiltration a better choice in some uses [22].

Several studies have shown the application of MBR in municipal wastewater treatment [21–24]. Literature also suggests application of MBR for wastewater treatment and water reuse in different industries including those producing wastewater containing heavy metals [25] and micro-contaminants [26], pharmaceutical industry [27], oil industry and refinery [28], and petrochemical industries [28–31]. Application of a membrane bioreactor results in high-quality water for different purposes. In case that the permeate from membrane bioreactor doesn’t meet the criteria for recycling, polishing steps such as nanofiltration or RO would be required.

Min et al. investigated removal of acetaldehyde, butyraldehyde and vinyl acetate in a 10 L side-stream MBR with polyethersulphone tubular ultrafiltration membrane which has organic loading rate of 1.1 to 2.0 kgCOD/m³/day and reported removal efficiency of more than 98% [32]. Application of membranes in petrochemical industries, have been investigated by Takht-Ravanchi et al. using MBRs with ultra- and microfiltration with pore sizes ranging from 0.05 to 0.4 μm in which RO is mostly used as a polishing step in industrial wastewater reuse [33]. Also Chung et al. used a MBR with polypropylene membrane for petrochemical wastewater treatment with a concentration of 400 mg/L phenol and observed a removal efficiency of 100% during 18 h [34]. In addition Galil et al. investigated treatment of a petrochemical wastewater containing BTEX with COD concentration of 2000 to 4000 mg/L and flow rate of 500 L/day using a pilot-scale hollow fiber MBR and achieved effluent COD concentration of less than 50 mg/L [35].

In another study by Visvanathana et al. wastewater containing petrochemical contaminants is treated by MBR which lead to COD and BOD removal of 62–79% and 60–75%, respectively [36]. Qin et al. investigated a flat-sheet MBR with Chlorinated polyethylene microfiltration membranes and operating volume of 48 L in which 40% of its volume is anaerobic. They treated wastewater with COD concentration of 700 to 2000 mg/L at HRT of 19 h and achieved effluent with COD concentration of less than 50 mg/L [29]. Hassani et al. have reported COD removal efficiency of 75% in treatment of oil refinery wastewater with taking advantage of a side-stream hollow fiber MBR with operating volume of 20 L [37]. Also the removal efficiency of more than 98% was achieved by Dosta et al. in treatment of petrochemical wastewater with Phenol concentration of 12 mg/L and HRT of 0.45 day using a pilot-scale submerged flat-sheet MBR with operating volume of 8 m³ [38].

Several investigations have been carried out to study treatment of petrochemical wastewater containing phenol and olefin using MBR [10,29,39]. High removal efficiency with different initial concentrations (47–500 mg/L) at HRTs of 1.5–7 days was achieved by MBR technology [36]. Despite high potential of MBR technology for industrial wastewater treatment, MBR plants have not been studied for the treatment of EO/EG unit, and a mixture of the wastewater of EO/EG and olefin units.

Since MBR efficiency and membrane fouling are highly dependent on feed characteristics and scale of operation [40–42], pilot-plant studies on wastewater are strongly recommended for industrial applications [39].

This article aims to investigate technical feasibility of MBR application for the wastewater treatment in Marun petrochemical complex EO/EG and olefin wastewater units. Regarding special characteristics of Marun petrochemical complex wastewater, this investigation as the first study is applicable in similar industries.

**Experiments**

The experiments were carried out in a pilot plant MBR located in Marun petrochemical complex, special economic zone of Imam Khomeini port petrochemical, Iran. The schematic diagram of the pilot plant is illustrated in Fig. 1. It consists of aeration and filtration tanks with a total volume of 2.5 m³ and has flow rate of 139 to 333 L/h.

A flat-sheet membrane with an area of 10 m² was immersed in the filtration tank. The MBR module was supplied by Microdyn-Nadir BC10 which was equipped with polyethersulfone (PES) membrane with pore size of 0.04 μm. Activated sludge was acquired from a petrochemical wastewater treatment unit. The

![Fig. 1. Schematic diagram of the pilot plant.](http://dx.doi.org/10.1016/j.jiec.2014.11.003)
pilot plant received wastewater from EO/EG unit wastewater tank with a residence time of 1 day. Also olefin unit wastewater entered the plant after passing through an oil separator unit. EO/EG unit wastewater treatment was conducted at different HRTs of 7.5, 9, 11, 13.5 and 18 h. Olefin wastewater was treated at an HRT of 12 h.

Furthermore, experiments were carried out using mixed wastewater with ratios of 1/1 and 2/1 (similar to their production capacity) and HRTs of 12, 18 and 24 h to investigate the treatment of mixed wastewater of EO/EG and olefin units.

Membrane fouling resistance was recorded in a computer using trans-membrane pressure (TMP) equipment. Membrane fouling resistances were measured by physical cleaning of membrane surface [43]. BOD and COD concentration measurements were carried out using standard methods [44].

Ethylene glycol concentration was determined by spectrophotometric analysis in an extract solution [45]. Formaldehyde and acetaldehyde concentrations in wastewater were measured by HPLC system with 2,4-dinitrophenylhydrazine (DNPH) method [46]. Phenol and BTEX components were analyzed by solid-phase extraction (SPE) and Gas Chromatography (GC) method [47].

Results and discussion

**EO/EG unit wastewater treatment**

Table 1 shows some characteristics of inlet and outlet flow of MBR pilot plant. As illustrated in the table, monoethylene glycol and acetaldehyde largely account for the high COD concentration in EO/EG unit wastewater while formaldehyde is less effective due to its low concentration. The remaining COD is related to heavier poly ethylene and few oil components in wastewater. Results indicate that monoethylene glycol is efficiently removed from wastewater. Also a 98% removal efficiency was achieved for acetaldehyde despite its slow biological treatment compared to ethylene glycol.

Variations of COD in MBR inlet and outlet flow under different HRTs are presented in Fig. 2. Although EO/EG unit wastewater has passed through balancing tank with 1 day retention time and regarding characteristics of this wastewater, COD concentration fluctuation is mostly considerable. As shown in this figure, fluctuation in effluent flow COD concentration is very low which demonstrates the ability of membrane bioreactor to tolerate high organic loading rate and COD concentration changes. In order to achieve high quality water by wastewater treatment process COD concentration changes should be minimized.

Fig. 2 also reveals that for HRTs higher than 13.5 h, effluent COD concentration would reach an average of nearly 50 mg/L which meets the criteria for surface water discharge.

Fig. 3 illustrates the COD removal efficiency of EO/EG wastewater at different HRTs using MBR pilot plant. As shown in this figure, COD removal efficiency was significant and developed up to 97.5% for HRTs more than 13.5 h. Achieving such high COD removal efficiency is considerable in a single steady bioreactor using activated sludge. It should be mentioned that wastewater of Marun petrochemical EO/EG unit contains negligible total suspended solids (TSS) and applying membrane filtration process does not lead to an effective COD removal.

Fig. 3 also shows the negligible difference for COD removal in HRTs of 13.5 and 18 h. It indicates that maximum COD removal in the range studied using MBR is achieved in the HRT of 13.5 h. But in shorter HRTs, as the HRT reduced, so did the COD removal and minimum COD removal occurred at HRT of 7 h.

The results indicate that if one could reduce the wastewater COD to 50% through primary pretreatment processes such as biofilters or UASB, the permeate COD could reach below 25 mg/L by considering a removal efficiency of 97.5% for this system. In addition, due to very low turbidity of the effluent (about 1 NTU), tertiary treatments could be used to achieve high quality water for different purposes in Marun petrochemical complex.

Fig. 4 displays COD removal to microorganism ratio and the COD removal at different HRTs. The COD removal to microorganism ratio can be treated as food/microorganism (F/M) ratio. The F/M ratio is a process control number which represents the ability to tolerate the inlet organic loading. Fig. 4 shows that COD removal to microorganism ratio in MBR is different and more than 0.17 gCOD/ gMLSS/day when treating EO/EG unit wastewater at variant HRTs.

In a similar way, Fig. 4 displays the descending rate of F/M ratio in HRTs of 7 to 13.5 h despite increase in COD removal efficiency. In low HRTs, ratio of total inlet organic loading rate to microorganism

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**Table 1**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>In (mg/L)</th>
<th>Out (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td>1730</td>
<td>155</td>
</tr>
<tr>
<td>BOD</td>
<td>1266</td>
<td>21</td>
</tr>
<tr>
<td>Monoethylene glycol</td>
<td>452</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>220</td>
<td>3.3</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>&lt;1.0</td>
<td>&lt;1.0</td>
</tr>
</tbody>
</table>

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in MBR is more than the required amount and thereby microorganisms are provided with more food compared to the higher HRTs. Although the removed organic load for every microorganism is higher, the microorganisms, in fact, consume only a small portion of the organic load and the rest leaves the system. But in HRTs higher than 13.5 h, COD removal to microorganism ratio is higher. Considering constant COD removal efficiency in this range, it can be concluded that the removed loading rate is equal in HRTs of 18 and 13.5 h. However reduction in biomass concentration led to an increase in COD removal to microorganism ratio over time. As a result, the HRT of 13.5 h is the optimum HRT for EO/EG unit wastewater treatment in Marun petrochemical complex using MBR. Also F/M ratio in industrial scale design should equal 0.176 gCOD/gMLSS/day.

**Olefin wastewater treatment**

Quality parameters of olefin unit wastewater are summarized in Table 2 for an HRT of 18 h. COD to BOD ratio is more than four which seems difficult to be treated biologically. The olefin unit wastewater mainly contains BTEXs and phenol. Among these components, concentration of benzene and ethyl benzene is considerable and their removal in MBR is 98% and 96%, respectively.

Table 2 indicates that at the HRT of 18 h, a COD removal of 85% is accomplished which is considerable compared to 50.5% at an HRT of 12 h. The noticeable difference in COD removal represents the significance of increasing HRT and in fact decreasing inlet organic loading in order to achieve high COD removal efficiency.

Foam formation was observed in the HRT of 12 h and during wastewater treatment process of olefin unit. Definitely, the possibility of foam formation in MBR is more than in activated sludge process, due to high residence time of sludge and consequently high concentration of bound EPSs [20]. Concentration of highly toxic components including BTEXs in the HRT of 12 h is higher compared to the HRT of 18 h which reduces microorganism activity and as a result curtails COD removal efficiency. In addition, high concentration of these toxic components increase the concentration of bound EPSs which lead to foam formation.

**EO/EG and olefin mixed wastewater treatment**

Hazardous contaminants including acetaldehyde in ethylene glycol unit wastewater and BTEXs in olefin unit wastewater have a concentration of 300 and 100 mg/L, respectively. In case that the wastewaters are mixed with equal ratios, contaminants concentration in mixed wastewater would decreased to half, so that acetaldehyde and BTEXs would have concentration of about 150 and 50 mg/L, respectively. Mixing the wastewater of EO/EG and olefin units leads to a decrease in toxicity and the concentration of contaminants in the mixed wastewater and improves the treatment efficiency of olefin unit wastewater. This also eliminates the need to establish two separate wastewater treatment units.

Fig. 5 displays COD changes in inlet and outlet flows at different HRTs and various mixing ratios. Fluctuation in COD concentration of inlet flow is mostly due to the fluctuation in EO/EG unit wastewater which was previously mentioned in Fig. 2. As shown in Fig. 5, outlet COD concentration in the HRT of 18 h is lower than the HRT of 12 h which is due to lower loading rate and toxicity in higher HRTs.

While the COD/BOD ratio in olefin and ethylene glycol units wastewater are about 4.0 and 1.33, respectively, the ratio in the mixed wastewater reached to 1.70. Since COD/BOD ratio in ethylene glycol wastewater is less than that of olefin unit wastewater, it was expected that mixing these two improve the treatment efficiency. It could be because of a decrease in the concentration of toxic components in olefin unit wastewater and the development of their biodegradability due to the effect of new nutrients such as monoethylene glycol. Also, foam formation didn’t occur when olefin unit and EO/EG units wastewater were mixed which indicates a reduction in toxicity of the inlet organic loading and subtraction of the concentration of bound EPS compared to the case that olefin unit wastewater entered MBR and foam formation occurred.

COD removal efficiency for the mixed wastewater of olefin and EO/EG units in different mixing ratios and HRTs is illustrated in Fig. 6. As the figure demonstrates, COD removal efficiency improved as the HRT and mixing ratio of the wastewater of EO/EG to olefin units enhanced. In the HRT of 12 h, COD removal of olefin unit wastewater diminished over the time, but COD removal of mixed wastewater developed which could be attributed to the
Toxicity of olefin wastewater and its negative effect on microorganism activities. In treatment of olefin unit wastewater which includes foam formation wastewater toxicity influences the MBR efficiency during the time of operations. This could be attributed to increase in accumulation of toxic components that don’t pass through the membrane. On the other hand, when the mixed wastewater is treated by MBR, COD removal efficiency improves by time. This is due to the presence of monoethylene glycol and its positive effect on the ability of microorganisms to tolerate toxic components. Therefore, the resistance and tolerance of microorganisms against toxicity of olefin unit wastewater increase.

It is observed that that when the wastewater of EO/EG and olefin units are mixed with a ratio of 2/1, a better treatment efficiency is achieved despite higher COD concentration of mixed wastewater. The amount of the produced wastewater in EO/EG and olefin units also follows the 2/1 ratio. COD removal efficiency of 93.5% and 96% was achieved for this mixing ratio at the HRTs of 18 and 24 h, respectively. Although 2.5% increase in COD removal efficiency is observed, the HRT of 24 h is not recommended because of the 33.3% increase in HRT and the same growth in footprint area. So the HRT of 18 h is sufficient for treatment of 2/1 mixing ratio.

Fouling study

Fig. 7 shows membrane fouling in different MLSS concentrations in the first week of operation. MLSS concentrations of 5, 6, 8, 9, 10 and 12 are related to the HRTs of 18, 13.5, 11, 9 and 1.7, respectively. Since MLSS concentration is the key parameter in membrane fouling in MBR [48,49], results are shown in terms of MLSS concentration. In each MLSS concentration, TMP raised as the time passed indicating increase in fouling over the operation time. The main cause of the fluctuation in TMP is changes in the inlet contaminant concentration which was pointed out in Fig. 2.

By ignoring MLSS concentration of 8 g/L and its corresponding HRT of 13.5 in Fig. 7, it is concluded that membrane fouling is directly proportional to MLSS concentration which is in agreement with previous studies [50,51]. MLSS concentration of 8 g/L is the maximum fouling in the treatment of EO/EG unit wastewater and occurred due to the change in membrane fouling mechanism over time. Typically, in MLSS concentrations of lower than 6 g/L and higher than 15 g/L, the MLSS concentration grows, so does the membrane fouling. However, between these two MLSS concentrations and especially in the range of 8–12 g/L, the reverse trend is observed which has been reported in previous studies [52,53].

Fig. 8 illustrates the average TMP for different MLSS concentrations. It can be observed that by rising MLSS concentration to nearly 8 g/L, fouling would increase. Yet higher MLSS concentration would lead to a decline in fouling growth rate and consequently diagram slope. In fact, in low MLSS concentrations, the tendency of the particles to settle on the membrane surface intensified as the MLSS concentration grows which lead to higher pore blockage and membrane fouling. When the MLSS reaches a particular amount (about 8 g/L), more increase in MLSS concentration leads to the formation of a porous layer of particles on the membrane surface called cake. The cake layer can protect the membrane from colloidal particles which are the major cause of pore blockage and membrane fouling in MBR. As a consequence, the growth rate of membrane fouling would decrease. Further enhancement of MLSS concentration results in the thickening of the formed layer on the membrane which is the governing fouling mechanism in high MLSS concentration [51,53]. In general, the change of fouling mechanism mostly occurs in MLSS concentrations of 8 to 12 g/L [19,51], and in the studied MBR the change in fouling mechanism was observed in this range (8 to 12 g/L).

The role of different kinds of membrane fouling in treatment of EO/EG unit wastewater is compared in Table 3. The MLSS concentration of 8 g/L which is the maximum point in membrane fouling in this study at the optimum HRT of 13.5 h for EO/EG unit wastewater treatment. It is shown that most of the membrane
fouling is due to pore blockage. Also reversible blocking resistance and irreversible resistance account for 54.44% of the total filtration resistance. Thus, only about 81.6% of total pore blockage could be removed by chemical cleaning. Furthermore, the gel resistance and cake resistance are almost equal and constitute 15% of the total resistance which is removable by physical cleaning. However, it should be noted that membrane fouling is the result of interaction between biological particles which are directly dependent on MBR feed. Therefore, results shown in Table 3 are obtained under special characteristics of wastewater used in this investigation.

Table 3

<table>
<thead>
<tr>
<th>Resistance</th>
<th>R [1/m] x 10^13</th>
<th>% of total</th>
</tr>
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<tr>
<td>Total hydraulic resistance</td>
<td>72.97</td>
<td>100.00</td>
</tr>
<tr>
<td>Membrane resistance</td>
<td>6.49</td>
<td>8.89</td>
</tr>
<tr>
<td>Concentration polarization resistance</td>
<td>4.86</td>
<td>6.67</td>
</tr>
<tr>
<td>Cake resistance</td>
<td>11.35</td>
<td>15.56</td>
</tr>
<tr>
<td>Gel resistance</td>
<td>10.54</td>
<td>14.44</td>
</tr>
<tr>
<td>Reversible blocking resistance</td>
<td>32.43</td>
<td>44.44</td>
</tr>
<tr>
<td>Irreversible resistance</td>
<td>7.40</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Conclusions

This study investigated the technical feasibility of wastewater treatment and water reuse in Marun petrochemical complex EO/EG and olefin units using an MBR pilot plant. COD concentration of ethylene glycol wastewater is in the range of 1000 to 2800 mg/L with an average of 1900 mg/L while olefin unit wastewater changes between 600 and 1200 mg/L and has an average of 900 mg/L. The COD concentration of EO/EG wastewater is because of its main components including monoethylene glycol and acetaldehyde which have concentrations of 600 and 250 mg/L respectively and other components such as polyethylene glycols, formaldehyde and others have a concentration of less than 25 mg/L. Also, the olefin unit wastewater often contains benzene and ethyl benzene.

The efficiency of the wastewater treatment EO/EG and olefin units in different HRTs was studied. In addition, treatment of a mixed wastewater of the EO/EG and olefin units in different ratios of 1/1 and 2/1 was investigated. Also, membrane fouling in different MLSS concentrations, quantity, and contribution of various resistances were analyzed. The results revealed that:

- The EO/EG unit wastewater is easily degradable using MBR and acetaldehyde doesn't affect the process of biological treatment. Thus, an average wastewater treatment efficiency of more than 97.5% was accomplished for the optimum HRT of 13.5 h and MLSS concentration of 8 g/L.
- COD removal to microorganism ratio which can be treated as F/M ratio diminished as the HRT increased and finally reached 0.176 gCOD/gMLSS/day at an HRT of 13.5 h and the MLSS concentration of 8 g/L. Further development of HRT leads to higher COD removal to microorganism ratio, though the removal efficiency didn't change so much and only concentration of microorganisms decreased.
- COD/BOD ratio of olefin unit wastewater is higher than 2 and is not easily biodegradable. So, foaming occurs at an HRT of 12 h. The wastewater treatment efficiency of 85% was achieved using MBR in an HRT of 18 h.
- The treatment efficiency of mixed wastewater of olefin and EO/EG units with the ratio of 1 to 2 was 93.5% in an HRT of 18 h. In case of a 24 h HRT, wastewater treatment efficiency of 96% was accomplished.

- In this study it was observed that membrane fouling growth rate is higher in range of 6 to 8 g/L compared to the range of 8 to 12 g/L. It was related to the change in membrane fouling mechanism and development of cake formation on the membrane surface as previously was explained by Brookes et al. [51] and Rosenberger et al. [53]. However for achieving a more precise explanation of this behavior, further research is required.
- In an optimum HRT of 13.5 h and the MLSS concentration of 8 g/L, 54.44% of total resistance is due to the pore blockage, only 81.6% of which can be removed by chemical cleaning. Also, cake and gel resistances are almost equal and account for 15.56% and 14.44% of the total resistance, respectively and can be removed by physical cleaning.
- The results demonstrate the MBR ability to tolerate COD fluctuation of EO/EG unit wastewater and stand toxic components in olefin unit wastewater. Also, MBR can efficiently treat mixed wastewater of EO/EG and olefin units and produce high quality water.

Conflict of interest statement

None declared.

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