Mitigation of Membrane Fouling in Waste Water Treatment Plants by Using MBBR & Sponge Membrane Bioreactor (Sponge-MBR)

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Abstract. A membrane bioreactor system is used to treat domestic wastewater by activated sludge-membrane bioreactor (AS-MBR). Two configurations; moving bed bioreactor, sponge-membrane bio reactor (MBBR & Sponge-MBR) and one nanocomposite membrane have been successfully designed to diminish membrane fouling caused by activated sludge. The classical phase inversion was harnessed to prepare zinc oxide nanoparticles embedded with polyphenyl sulfone nanocomposite membranes ZnO / PPSU using 1.5 g ZnO. Prepared nanocomposite membrane surface was fully characterized by a series of experimental tools, e.g., scanning electron microscopy (SEM), atomic force microscope (AFM), and contact angle (CA), pore size and pore size distribution. The testing procedure was performed through an AS-MBR system as a reference and the results were compared with the configurations obtained from the moving bed (MBBR-MBR) and sponge-MBR, in presence of layer of dense polyurethane sponge (15 x10 x1.5 cm) systems. The fouling reduction of the membrane has improved significantly and thus the overall long-term increased by 145% compared with the control AS-MBR configuration. The experimental results showcased that sponge-MBR were capable of adsorbing activated sludge and other contaminants to minimize the membrane fouling. The sponge-MBR was capable of eliminating nitrogen and phosphorus by 71% and 80%, respectively.

Keywords. Waste water treatment plants, MBBR, Sponge-MBR, and Nanocomposite membrane.

1. Introduction
Limited water resources and growing urbanization demand more modern technology to maintain water quality. One of the significant factors influencing the quality of water is the accumulation of nutrients in water sources. A number of environmental problems are caused by high concentrations of organic matter (e.g. chemical oxygen demand (COD), phosphorus (P) and nitrogen (N)) such as eutrophication, oxygen consumption and toxicity. To reduce their environmental effects, it is also important to remove these contaminants from waste water. Biological processes are an environmentally safe and cost-effective alternative to the chemical treatment of waste water. Biological processes based on suspended biomass (i.e. activated sludge processes (AS)) in municipal waste water plants are effective in reducing organic carbon and nutrients. However, there are some problems with sludge settlement and the need for large reactors, storage tanks and biomass recycling [1, 2]. For the removal of organic carbon and nutrients, biofilm processes have proved to be reliable
without some of the problems of activated sludge processes [3-5]. The biological treatments of sewage, two methods are widely used: activated sludge and trickling filters. A compilation of these two technologies is a moving bed biological reactor (MBBR). There are two types of biomass in the MBBR: suspended flocks and a biofilm attached to the carriers. It can work at high organic loads and is less vulnerable to hydraulic overloading [1].

The status of membrane bioreactors (MBRs) as a prominent waste water treatment system is well known. The MBR system for substituting traditional biological reclamation techniques for carbon source and nutrient separation has been established over the past few decades [6, 7]. The inherent membrane fouling is still the leading constraint, despite the relatively advanced state of all MBR categories, impeding their widespread application by reducing their performance and, indeed, raising maintenance and operating costs. In the literature, unlimited methods to minimize the fouling effects of the membranes have been witnessed. These techniques are expanded by grafting with specific functional groups from surface hydrophilicity revision, adding functional antibacterial materials/nanomaterials and others with catalytic characteristics to degrade foulants on the membrane surface [8-11]. Among these versatile techniques, impregnating functional nanomaterials (NMs) in the membrane industry has attracted the flourishing research community in the present days. NMs will provide a huge opportunity to treat miscellaneous wastewater streams with limited fouling potential of MBRs.

2. Materials and methodologies

2.1. Materials

Polyphenyl sulfone (PPSU-Radel R-5000), with an average Mw of 50KDa, was purchased from Solvay Advanced Polymers (Belgium). N-methyl-2-pyrrolidone (NMP), at 99.5% purity was employed as a solvent and purchased from Sigma–Aldrich (St. Louis, MO). ZnO nanoparticles (10-30 nm diameters) were purchased from SSNano, USA. Characteristics of the moving bed bio-media utilized in EMBBR configuration are given in table 1.

| Material | Plastic                      |
|----------|------------------------------|
| Shape    | Corrugated cylinder          |
| Density  | 0.95 g /cm³                  |
| Dimensions | Sponge-Membrane bioreactor configuration |
| Specific surface | Specific surface             |

2.2. Nanocomposite membrane preparation

All ZnO-PPSU nanocomposite membranes were prepared through the non-induced phase separation (NIPS) process. In brief, 15wt. percent of PPSU in 85wt. percent of NMP was dissolved and stirred overnight until a homogeneous dope solution was reached. Three loading weights (0.5, 1, and 1.5 g) of ZnO NPs were individually applied to the dope solution and ultrasonically dispersed and degassed for 30 minutes. A small amount was poured on a glass substrate and cast under atmospheric conditions through a motorized thin-film applicator with a 200μm clearance gap. Subsequently, the prepared films were directly immersed in deionized water (DI) bath for phase separation. After that, the resulting membranes were thoroughly rinsed to remove the residual trace solvent. The membranes were ultimately put in a 35-percent glycerol solution for two days to keep the membrane structure safe [8].

2.3. Polyurethane sponge preparation

In the Sponge-MBR system, polyester-urethane sponges (PUSs) were used: coarse pore structure (30–35 kg / m³ density with 40 cells per 25 mm) and fine pore structure (20–22 kg / m³ density with 75 cells per 25 mm). The dimensions of both the coarse and fine pore structure sponge sheets were 10 × 15 × 1.5 cm. As measured by (AFM), the PPSU / ZnO flat sheet membrane module had an average pore size of 235 nm, and a surface area of 8.87 × 10⁻⁴ m². Two sub-layers above the PPSU flat sheet
membrane cell were then wrapped in the membrane cell. The top layer consisted of a coarse-pore-
structure sponge; the bottom layer was comprised of fine-pore-structure sponge.

2.4. Membranes surface characterization
The surface and cross-sectional morphological changes were visualized by scanning electron 
microscopy (SEM). The SEM images were taken with a TESCAN VEGA3 SB (EO Elektronen-Optic-
Service GmbH, Germany) device at an accelerating voltage of 30 kV. The cross-sections of the flat 
sheet membranes were prepared prior to imaging by freeze fracturing in liquid nitrogen while a thin 
chromium coat was sputtered on all membranes. The atomic force microscope (AFM) inspected the 
surface topography, pore size and pore size distributions of the nanocomposites. Sessile drop 
measurements were used to characterize the surface wettability of the ZnO-PPSU membranes. For this 
reason, a contact angle instrument (CAM 110-O4W, Taiwan) was employed. Approximately 4 μl of 
DI water was mounted on each membrane surface and the instrument software captured the contact 
angle between the drop and the surface. There were at least three triplicates taken, and average results 
were displayed.

2.5. Performance evaluation of ZnO-PSU nanocomposite membranes
The water permeates flux and separation measurements of the membranes were conducted in 
laboratory cross-flow filtration apparatus. All experiments were performed with a membrane cell 
having an effective membrane area of $8.87 \times 10^{-4}$ m$^2$, under a $-0.4$ bar vacuum and feed temperature of 
$25^\circ$ C. The pure water permeability (PWP) was calculated as follows:

$$ \text{PWP} = \frac{V}{(t \cdot A \cdot P)} $$

(1)

Where; PWP is the pure water permeability of the membranes (l/m$^2$ h bar), V is the permeate volume 
collected (L), t is the collection time (h), P is the transmembrane pressure, and A is the active 
membrane surface area (m2). The retention R (%) was estimated as given in equation 2, below:

$$ R (%) = \frac{(1-C_p)}{C_f} \times 100 $$

(2)

Where; $C_f$ and $C_p$ are the concentrations of the feed and permeate, respectively.

Fouling and permeation studies were performed using 10000 mg / L AS mixed liquor suspended solids 
(MLSS). The membrane pure water flow was measured at $-0.4$ bar for 30 min, then the permeation 
flux was measured at $-0.4$ bar for 90 min and determined as follows:

$$ J = \frac{M}{(A \cdot \Delta t)} $$

(3)

Where; J, M, t and A are the permeate flux, the mass of the permeated water, permeation time and 
effective membrane area, respectively. To estimate the fouling behavior in the system, the percentage 
reduction in permeate flux (PRPF) was calculated as given below:

$$ \text{PRPF} (%) = \frac{(J_i-J_n)}{J_i} \times 100 $$

(4)

Where; $J(i)$ is the initial permeation flux while $J(n)$ is the permeate flux at a given time. The performance 
was evaluated for all membranes at various (0.5, 1 and 1.5) g ZnO NPs loading against 
activated sludge, and membranes manifested highest performance will be adopted for the further tests.

2.6. MBR Experimental setup
Step one: For the experimental tests of the ASMBR system, an actual source of waste water collected 
from a local domestic wastewater treatment plant (WWTP) in Al-Nassiriayh city, Iraq, was used. All 
Waste water characteristics are summarized in table 2.
Table 2. Characteristics of domestic wastewater in AL-Nassiriyyah City.

| Pollutant | Influent concentration (mg/l) | Max. allowable limit (mg/l) |
|-----------|--------------------------------|----------------------------|
| COD       | 450–800                        | 100                        |
| NH3       | 150 – 180                      | 0.02-0.06                  |
| NO3       | 25-70                          | 50                         |
| P         | 16 – 24                        | 3                          |
| EC        | 2393-5102                      | 200 - 800 μS.cm⁻¹          |
| TDS       | 500-860                        | 100                        |
| TSS       | 89-113                         | 20                         |

The proposed design of the ASMBR pilot plant used in the present work consisted of 40L aeration tanks with an effective volume of 32L. In the schematic diagram of the AS-MBR system (figure 1), waste water was fed into the reactor via a batch feeding to regulate the feed rate while the effluent flow rate was controlled by a suction pump.

![Figure 1](image)

**Figure 1.** (A) Real picture for AS-MBR system, (B) Schematic diagram of the AS-MBR lab-scale MBR system.

Air was pumped from the base of the aerobic tank to provide the necessary oxygen for the microorganisms. The air was pumped by a perforated tube under the base of the aeration tank to ensure the uniform air bubble distribution. In addition, a cross-flow velocity is defined across the flat-sheet membrane surfaces to minimize MBR fouling. An intermittent filtration mode, i.e. 10 min suction and 1 min repose (non-suction) was adopted here. The AS had been grown locally from Al-Rustumiah WWTP, Baghdad-Iraq, while the biomass had been acclimatized for two months in the
waste water to ensure stable conditions prior to the experiments in membrane filtration. The activated sludge cultivated was transferred to the AS-MBR pilot plant treatment system for treatment of the real Nasiriyah domestic wastewater. At 10000 mg/L, 24-days and 0.2 g COD/g MLSS-day, the concentration of MLSS, the retention time of sludge and organic loading rate were preserved. With a module cell dimension of 10 cm x 15 cm, the effective membrane area was 0.000887 m². All tests were conducted under the conditions of -0.4 bar and 25 ± 2 °C.

*Step Two:* For two configurations of sponge-MBR and MBBR-MBR, two similar tanks with a working capacity of 40L and an effective volume of 32L were used. The sponge-MBR configuration consisted of a membrane-module tank, an aeration system and a membrane-module two-layer sponge to avoid fouling, as shown in figure 2. Due to the coexistence of both suspended biomass and biofilm and membrane separation, the configuration of the MBBR-MBR is especially useful in slowly growing organisms where the nitrate to be preserved and removed within a WWTP restricting the required reactor volumes. In this matter, the main objective of this work is to reduce fouling in MBR and to investigate efficiency in terms of removal of carbon and nutrients.

![Sponge-MBR reactor](image1)

**Figure 2.** Sponge-MBR reactor.

The characteristics of the bio-media are shown in table 1. The AS-MBR system was the same for the MBBR process, adding the bio-media to the aeration tank. As shown in the process flow diagram in figure 3, the process consists of an MBBR system, plastic media, biological reactors, and a membrane with ancillary equipment. The MLSS concentration was controlled by means of sampling during the study. Wasting was not initially performed until the MLSS concentrations in the aerobic reactor increased above 6 g/L. This happened about 30 days after the beginning of the operation. The plastic media filled the aerobic reactor with a particular surface area of 260 m²/m³ (table 1), and the aerobic tank fill percentage was 40 percent. Biofilm was formed in the aeration tank on the carriers, but low to no biofilm growth was observed in the MBR reactor.

![Moving bed membrane bioreactor (MBBR)](image2)

**Figure 3.** Moving bed membrane bioreactor (MBBR).
For the MBBR process, the AS-MBR system was the same, adding bio-media to the aeration tank. As shown in the process flow diagram in figure 3, the process included an MBBR system, plastic media, biological reactors, and a membrane with ancillary equipment. The plastic media filled the aerobic reactor with a particular surface area of 260 m² / m³ (table 1), and the aerobic tank filled 40 percent. Biofilm was developed in the aeration tank on the carriers.

3. Results and discussion

3.1. Membrane surface characteristics

The membrane prepared at 1.5 g showed the optimum performance for the used amount of ZnO. The characteristics of the membranes are seen in figure 4 and table 3, respectively. There were two layers of a standard cross-section structure; a sponge structure with a large layer of macropores near the bottom surface and a finger-like structure near the top surface (figure 4A). This influence of the inclusion of nanoparticles was more explicit on the membranes' top surface. On the surface, a semiporous surface with low pore density and clear homogeneous diffusion of ZnONPs was observed (figure 4B). Characteristics of surface roughness was scanned by AFM (figure 4C). It was found that the roughness parameters, Ra and Rms, were 32.5 and 37.6 nm respectively (table 3). Figure 4D shows the mean pore size and the cumulative distribution of pores.

![Surface characteristics of the nanocomposite membrane](image)

**Figure 4.** Surface characteristics of the nanocomposite membrane (A) SEM cross-section, (B) SEM surface (C) AFM, and (D) granularity cumulation distribution of pores.

| Characteristic                        | Value          |
|--------------------------------------|----------------|
| mean pore size (nm)                  | 72.57 nm       |
| granularity cumulating distribution of pores (nm) | 35-120 nm         |
| mean roughness, ra (nm)              | 32.5 nm        |
| Rms                                  | 37.6 nm        |
| contact angle                        | 48°            |
3.2. Membranes performance and long-term operation

The permeation characteristics of the membranes were characterized in order to compare their efficiency in short- and long-term operations. Figure 5 illustrates the role of nano additives ratio inside the polymeric matrix on the pure water flux (PWF) of these membranes. The PWF was increased by 42.7 percent (39.5-56.37 l/m².h) compared to that of the pristine PPSU membrane at 0.5 g ZnO membrane. For the membrane prepared with 1 g ZnO NPs, this improvement reached 135.28 l/m².h. An additional increase of one-third (180.37 l/m².h) with a further increase (1.5 g) in the ZnO NPs ratio was seen with regard to the former nanocomposite membrane. Thus, due to the addition of 1.5 g ZnO NPs, the entire improvement in the permeate flux was 357 percent higher compared to the control PPSU membrane. Nevertheless, it could be inferred here that the optimum amount of NPs was 1 g, as the PWF showed a breakthrough 3 times greater than other nanocomposites, compromising between flux enhancement and Nano additive quantity.

![Figure 5. DI Water flux for neat and modified membranes.](image)

Compared to the pristine membrane, figure 6 shows the long-term operational impact on the performance of the ZnO NPs modified membranes. Relatively, during the initial six days of ASMBR operation, the permeate flux of the pristine PPSU membrane was almost stable. This membrane was continuously operated for 35 days before membrane cleaning was required. However, the permeation flux of the 0.5 g membrane of ZnO NPs showed a sharp decrease after 11 days, while the operation continued for 40 days with the ASMBR. The increase to 1 g of nano additives in the dope solution resulted in a significant increase (up to 20 days) in the long-term operation of the nanocomposite membrane. This improvement was more apparent and continued beyond the 30-day membrane threshold prepared with 1.5 g ZnO NPs, before a significant decrease began to be observed. The former two membranes were operated in ASMBR for 36 and 45 days, respectively, before cleaning was requested.

The improved hydrophilicity of the ZnO modified membranes was the main reason for the stability of the permeated flux values. The experimental results of the long-term operations show that all prepared nanocomposite membranes can be used to treat wastewater through the ASMBR process. The results showed that the membrane prepared for the highest load (1.5 g Zn ONPs) has been operational for the longest time and the following stages in the sponge-MBR and MBBR systems were chosen. These systems (MBBR and Sponge - MBR) have been tested to reduce the fouling and improve performance of stage one. The MBBR system consists of an activated sludge on the surface medium which reduces the concentration of the active sludge in the solution (main cause of fouling). The MBBR system The SMBR system? consists of two sponge layers, which reduce membrane fouling by the theory of absorption. The effect of the sponge layers on long-term increased from 31 to 45 days to which PPSU
membrane increased by about 45% of 1.5 g, as shown in figure 7. The sponge layers absorbed the contaminants that cause membrane fouling. During operation, these layers were filled with active sludge that facilitates the biological removal.

**Figure 6.** Effect of ZnO NPs loading weight on the lifetime of the membranes, in the AS-MBR system (stage I).

**Figure 7.** The effect of MBBR & SMBR on lifetime of the PPSU/ZnO NP membranes stage II.

Figure 7 also shows the effects of the moving plastic bed (40% of the tank volume) on long-term period which increased about 16% (from 31 to 36 days) of the 1.5 g PPSU membrane. The moving bed holds a portion of the activated sludge on its surface, which improves membrane efficiency and extends the working time of the membrane to 70 days (due to the activated sludge, one causing fouling of the membrane). Furthermore, these layers with accumulated activated sludge (activated concentration of sludge) will increase the efficiency of biological treatment as described in the following paragraphs.
3.3. Biological treatment

The influential COD was between 500 and 800 mg / L in these various configurations. The efficacy of COD removal in the net PPSU membrane was found to be about 75 percent and the COD removal in all membranes with various ZnONP concentrations was around 75-85 percent. It can also be concluded that there are only small differences in the removal of COD among various concentrations of ZnONPs in the casting solution. MBR is used to remove soluble COD [12]. For example, the different removal efficiencies between the AS and AS-MBR systems are due to the membrane removal of soluble COD and the high concentration of MLSS in the MBR system. Generally, AS-MBR shows excellent performance in the removal of COD by membrane separation in different industries [13]. The performance of sponge - MBR (SMBR) COD removal measures 85% as shown in figure 8.

![Figure 8. COD removal efficiency for: activated sludge (AS), activated sludge-MBR (AS-MBR), sponge-MBR (SMBR) and moving bed bioreactor-MBR (MBBR-MBR) experiments.](image)

Figure 8 summarizes the removal of COD from AS, AS-MBR and SMBR experiments. The removal rate of COD for AS systems measures 50 percent, the AS-MBR configuration measures 75 percent, the SMBR configuration measures 85 percent (when HRT = 8h and SRT = 25d), and the MBR-MBBR configuration measures 88 percent (when HRT is reduced to 4h). The use of sponge layer as a biomass support, which increases contact between microorganism and the organic substrate, may explain significant COD removal with decreasing HRT. The literature provides several conclusions about the impact of HRT on the removal of COD. Molina et al., [14] have shown that the removal effectiveness decreases with increasing HRT and the efficiency increases with increasing SRT. In addition, HRT and SRT deduction were studied.

3.4. Nutrient removal

3.4.1. Nitrogen removal. The NH$_3$ concentration of the influent AS system, fluctuated between 145 mg/L and 160mg / L, and the NO$_3$ concentrations, fluctuated between 30 and 40 mg / L, as shown in table 4. However, the efficiency of removal in the AS system was around 80 percent. The average influent concentration of NH$_3$ was 160 mg / L for the AS-MBR configuration with removal efficiency about 85 percent. Success nitrification process in the AS-MBR system was indicated by these results. A rise in the MLSS in the ASMBr, which increases sludge age, can be attributed to ammonia removal efficiency, which enables an integrated process to maintain huge amounts of nitrobacteria and ensures a great nitrification impact, as proposed by [15]. With regard to the effects of different amounts of ZnONPs on the casting solution of PPSU membranes, it can be noted from table 4 that the removal of
NH$_3$ for membranes prepared from net PPSU and membranes prepared from PPSU / ZnO with different amounts of ZnONPs were within the very narrow range of 80 to 85 percent. Therefore, with the addition of ZnO NPs to the casting solution, it can be concluded that there is no effect of ZnONPs on NH$_3$ removal efficiency. The efficiency of NH$_3$ removal depends on the biochemical process, referring to the oxidation of ammonia (NH$_3$) into nitrate (NO$_3$) via nitrite (NO$_2$) depending on the two groups of nitrite oxidizing bacteria (NOB) and ammonia oxidizing bacteria (AOB).

In the Sponge-MBR (SMBR) technique, table 4 indicates NH$_3$ removal. The HRT is 8 hours, the average influent NH$_3$ concentration is 150 mg / L in this experimental setup, and the average removal performance is 95 percent. These principles prove that this process is completely nitrification and denitrification. Additional denitrification in the sponge layer may explain this increment. Nitrification and denitrification bacterial growth can be hosted by the coarse sponge surface, which consists of large pore sizes, where the top surface of the sponge represents an aerobic micro environment and the inner surface represents an anoxic micro environment, resulting in more aerobic bacteria on the top surface and more anoxic bacteria on the inner surface. The NH$_3$ removal seen in table 4 was around 88 percent of the MBBR configuration. These results indicate that the nitrification role of the media is more important than that of the suspended biofilm in AS bioreactors. Due to the different surface properties, flocs can facilitate faster molecular oxygen diffusion and lead to faster ammonia oxidation than in biofilm systems [16]. Nitrate reduction (denitrification) in the bioreactor containing NO$_3$-N continued incredibly rapidly within the first 24 hours, showing high denitrification efficiency of the MBR-MBBR.

3.4.2. Phosphorus (P) removal. For the AS system, table 4 indicates the influent P concentration fluctuating between 12 and 18 mg / L and the effluent P concentration fluctuating between 8 and 11 mg / L. In the AS system, the removal efficiency was approximately 35 percent. The variation of influences and effluents for P was between 15 and 18 mg / L in the AS-MBR system. The efficiency of phosphorus removal was limited, achieving approximately 52 percent, equal to the average effluent concentration of 7-8.5 mg / L. These results (low P removal) because of the activated sludge, need to be separated from the phosphorus concentration by the anaerobic process tank before the aerobic tank, as mentioned in previous literature.

In the SMBR configuration, P removal was about 71 percent, the average P influent concentration was 16 mg / L, with an effluent concentration of 4.48 mg / L. The results also show that the removal of P increases due to the sponge effect. In the MBBR process, biomass grows both as suspended flocs and as attached biofilm. In this method, carrier elements cause a higher concentration of biomass to be maintained in the reactor compared to the suspended growth process, such as activated sludge. For a given reactor volume, this increases the biological treatment capacity. The concept of the MBBR process is a continuous flow process that combines the two separate processes (attached and suspended biomass) by attaching small high density polyethylene (HDPE) biofilm carrier elements with a large surface area and a slight density to the tank for attachment and growth of biofilm. The average concentration of influent P is 17 mg / L and the average efficiency of removal is 80%, with effluent concentrations of 3.4 mg / L.

For 21 d, a PPSU/1.5 mg ZnO flat sheet MBR was used to investigate the performance of each of the AS, AS-MBR, SMBR and MBBR systems. The phosphorus removal measures are 35 percent in the AS, 52 percent in the AS-MBR, 70 percent in the SMBR and 80 percent in the MBBR respectively. The results suggest that the moving bed media for the MBBR system is an optimal biomass support medium. The P removal also shows that the accumulation of phosphate organisms on the sponge layer will achieve high phosphorus removal, as well as excess phosphorus uptake. In addition, a portion of the phosphorus is biologically removed by microorganisms attached to the sponge and in the MLSS, since P is an important biomass growth nutrient [17].
Table 4. Experimental result for aS, ASMBR, sponge-MBR and MBBR

|                | AS      | ASMBR   | SMBR    | MBBR    |
|----------------|---------|---------|---------|---------|
| NH₃ (mg/l)     | Influent| 153     | 160     | 150     | 145     |
|                | Effluent| 30      | 24      | 8       | 26      |
|                | Removal | 80.3    | 85      | 95      | 88      |
| NO₃ (mg/l)     | Influent| 35      | 32      | 40      | 38      |
|                | Effluent| 28      | 24      | 3.9     | 3       |
|                | Removal | 28      | 25      | 90      | 92      |
| P (mg/l)       | Influent| 12      | 16      | 16      | 17      |
|                | Effluent| 7.8     | 7.7     | 4.5     | 3.5     |
|                | Removal | 35      | 52      | 71      | 80      |

4. Conclusion

To meet with today's environmental concerns, efficient and low-energy water purification technologies are highly desirable. A low-cost approach was established during this work to an efficient degradation of organic pollutants and anti-fouling of membrane. This was carried out through two configurations:

First configuration: Harnessing the structure of the sponge inside MBR. In addition to functionalization of the sponge to be used as an antifouling of membrane, the sponge has shown a high pollutant adsorption and oxidation. In the meanwhile, a phase inversion was used to prepare nanocomposite membranes of Zinc Oxide PUS at a loading weight of 1.5 g. Based on the optimal results obtained in the experimental results, the aforementioned additive ratio was chosen. A series of experimental tools, such as SEM, AFM, contact angle, pore size and pore size distribution, have fully characterized the prepared nanocomposite membrane surface. The results showed that the mean pore size was 72.5 nm with a large pore size distribution varying from 35-120 nm. The results were 48, 32.5 nm and 37.6 nm for hydrophilicity, Ra and Rms, respectively. The test procedure was performed through an ASMBR and was compared with the results obtained with sponge – MBR (SMBR). The sponge was added as a pre-treatment to encourage the removal of the organic matter and reduce membrane fouling.

Second configuration: The concept of the MBBR is to merge the two separate processes (attached and suspended biomass) using the moving bed in the device. This research could be appropriate to analyze the feasibility of using the moving bed biofilm method as an ideal and reliable alternative for the complete removal of nutrients from domestic waste water. The aeration transition mode offered during the experimental work will have a major effect on the effectiveness of waste water treatment. The moving bed technology can help to evaluate the viability of waste water treatment by using both the attached growth system and the suspended growth system, as well as stopping the fouling membrane from occurring to the SMBR system.

List of symbols

| Symbol | Description                        |
|--------|-----------------------------------|
| AS     | Activated sludge process          |
| AS-MBR | Activated sludge process-Membrane bio reactor system |
| SMBR   | Sponge-Membrane bioreactor configuration |
| MBBR   | Moving bed bioreactor process     |
| NP₅    | Nano particles                    |
| SEM    | Scanning electron microscopy      |
| AFM    | Atomic force microscope           |
| CA     | Contact angle                     |
| PUSs   | Polyester-urethane sponges        |

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