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Formation Mechanism and Performance of Dynamic Membrane Technology for Municipal Wastewater Treatment - A Review

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Abstract

This review presents the recent state of Dynamic membrane (DM) technology as the alternative for Ultrafiltration, Microfiltration and membrane bioreactor (MBR) system. DM technology involves the application of physical materials such as mesh or clothes as a barrier that enhances the formation of a cake layer on their surfaces. This technology has been used extensively in local filtration processes. DM has a lower risk of membrane fouling, lower capital cost and requires little energy compared to MBR. The performance of DM was evaluated to obtain a suitable method for membrane filtration technology. Further suggestion to encourage the application of this technology in wastewater treatment plant was given.

Keywords: Dynamic membrane; Membrane filtration; Wastewater treatment; Membrane bioreactor

Introduction

Water is one of the essential elements of human life as the body cannot survive longer than few days without adequate water. As such, there is a need to ensure that individuals get access to clean water. One of the reasons for the lack of availability of clean water is that over 70% of the world freshwater is used for irrigation purpose [1-5]. In light of this, there is a considerable need for the treatment, recycle and reuse of wastewater. Several studies documented different wastewater treatment processes for reuse and resource recovery. This review presents the advantages of the dynamic membrane (DM) for wastewater treatment.

DM was first reported in 1965 by workers at the Oak Ridge National Laboratories. Their initial aim was to apply DM in reverse Osmosis for desalination. Attention on DM shifted as time goes on to fruit juice concentration, protein retention, domestic water reuse and industrial wastewater treatment. Membrane technology, in general, has been used extensively to separate solid from liquid in biological treatment (aerobic and anaerobic) and physical application for many years. There has been upcoming interest in combining biological wastewater treatment with a membrane in membrane bioreactors (MBRs), this showed several advantages such as small footprint and improved effluent quality [6]. However, the major shortcomings of MBR treatment processes are related to high energy demand, the cost of the membrane, low flux, and fouling control. DM technology is a promising step to solve problems that arise from MBR treatment processes [7-10]. DM which is also known as secondary membranes, is usually made to form on underlying support of different kinds of cheap materials such as filter cloths, membrane, woven and nonwoven fabric and mesh can be used as the supporting layer instead of ultrafiltration (UF) or microfiltration (MF) membrane for the formation of dynamic membrane layer, when the filtered effluent consist of solid substances such as flocs and microbial cells. Colloidal and some organic particles that usually cause fouling of the membrane will be captured or trapped in the filtration layer of the biomass, preventing the fouling of the materials in support of the membrane [7,11]. DM technique is simple and common and the present means of membrane modification. Different particles of different sizes in a solution are rejected by a porous support to form a dynamically porous filtration layer.

One of the most prominent benefits of DM is that the membrane may be no longer important since particles rejection is achieved by the secondary membrane layer and this can be formed and reformed as a self-forming dynamic membrane. Continuous processes of DM formation and removal could reduce the permeability losses of the membrane as encountered in conventional MBRs [12]. Since the 1960s, many studies have been conducted on DM starting from the attempt on physical filtration to membrane bioreactor (MBR) applications as the formation of DM mechanism and the application varies.

DM technology in anaerobic membrane bioreactor was introduced into the treatment of municipal wastewaters in several studies [13-16] and the result showed that 98% effluent quality was obtained in the treatment process. Once the membrane is heavily fouled, the DM layer can be replaced by another newly deposited layer. Thus, this will spare the expense of buying and physically replacing new membrane. Recently, many studies have been focusing on the use of fabric or meshes as the materials to support the membrane formation in solid versus liquid separation in the aerobic wastewater separation. When Industrial filter cloth material was used, the turbidity permeate was less than 9NTU, the formed cake layer was found out to be the major resistance factor while the suspended solids (SS) was zero. Biomass layer of the DM On a mesh consisted of a gel layer and a cake layer. The structure of the gel layer looks almost like the conventional membranes and served as the major structure in the permeability of the dynamic membrane. The formation process of a dynamic membrane was divided into four stages based on the behavior of the flux under constant filtration pressure and these are substrate formation, separation layer formation, fouling layer formation and the filtration cake formation respectively.

Problems and future perspective of DM were evaluated from the literature reviewed to further enhance the application and the functionality DM technology in municipal wastewater treatment in

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order to encourage the use of this treatment method in wastewater treatment.

Literature Review

Many research base on the combination of DM with other processes in wastewater treatment has been successful with the effluent quality ranging from 95 to 96% were obtained respectively [15]. Highlighted a comprehensive evaluation of the current approach of DM technique as the possible alternative to membrane bioreactor (MBR). A review of the function and capability of the dynamic membrane was presented and evaluated and they came to conclusion that a compressible and porous layer formation, which can serve as an obstacle that reduces the passage of particles of different sizes through the membrane formation layer, is the most important criteria for achieving the best performance in DM applications in wastewater treatment [15,17]. Figure 1 demonstrates the dynamic cake layer [14]. Further carried out an investigation to check the characteristics of dynamic membrane bioreactor (DMBR) for wastewater treatment; this was done to be sure of the critical flux and the performance of dynamic membrane during operation in wastewater treatment. Various analyses were carried out and they concluded that the membrane demonstrated excellent particles rejection capacity within the membrane layer and high critical flux of activated sludge DM was observed. They further postulated that cation bridging will play a vital role in forming gel layer along the stainless steel mesh [14] as shown in Figure 2.

In order to determine the quality and strength of dynamic membrane technology as a barrier that filter the passage of particles in anaerobic membrane bioreactors for the treatment of a very high concentration of wastewater, [15] made use of a monofilament weaved fabric as a support material for the formation of the membrane. An anaerobic dynamic membrane bioreactor (AnDMBR) was operated under several operational conditions, together with different sludge retention times of 20 and 40 days in order to evaluate the effect of sludge retention time on both dynamic membrane filtration characteristics and biological performance. From the result, high COD removal efficiencies exceeding 99% were obtained. They concluded that the applicability of DM technique for the treatment of concentrated wastewater is possible, as it possess the quality and characteristics that will enable it to be used as an alternative for MF or UF membranes. Polypropylene monofilament filter cloth was used as support material to form a DM layer and provided a very high quality filtration by this self-forming dynamic layer [15]. Zhang et al. [18] also carried out an experiment to study the formation mechanism of DM on anaerobic membrane bioreactor at a high flux of 65 L/(m^2.h) and the formation mechanisms were studied. The result showed that the dynamic membrane was formed by the sludge particles available in the wastewater and colloids content such as SMP and EPS. According to the index of SS/ cake volume, the accumulation process could be divided into three stages of the formation of the separation layer, the stale growth stage, and the fouling stage respectively [18]. Figure 3 represents the schematic diagram of the AnMBR.

An investigation on using DM for municipal wastewater was carried by Ref. [14], they investigated the features of bio-enhanced powdered activated carbon dynamic membrane reactor for municipal wastewater treatment in the laboratory scale continuous flow mode. The BPDM was amenable to continuous operation at high filtration fluxes in the range of 100 to 235 L/m^2.h. The means particle sizes of the BPDM increased from the top cake layer to the middle cake layer, with the largest mean particle sizes found in the bottom cake layer. They concluded that the BPDM demonstrated good filtration capacity. It was amenable to continuous operation at high filtration flux in the range of 100 to 235 L/m^2.h, which corresponds to filtration times of approximately 8 h to 22 h at a TMP of 40 kpa and they finally concluded from the experiment that the addition of PAC might facilitate the cake layer filtration [14]. Another work on using DM for municipal wastewater treatment was done by Ref. [19]. They check the capability and operational characteristics of dynamic membrane bioreactor for municipal wastewater treatment. They introduced an approach that used an industrial filter cloth material instead of the conventional MF/UF membrane to build a membrane bioreactor for wastewater treatment. The formation and filtration capacity of the dynamic membrane and the performance of the dynamic membrane bioreactor (DMBR) for treating municipal wastewater were studied and analyzed. The results of the batch tests showed that the dynamic membrane could be formed on the filter cloth surface very fast and developed steadily, it played an important role in rejecting particulate matter and also shows that higher sludge concentration could contribute to the formation of dynamic membrane. Conclusion was drawn from the study that the filter cloth could separate activated sludge effectively, even at the very beginning stage of first 5 minutes. The results of the batch test with the dynamic and new naked membrane in the filtration of the standard turbidity solution proved that the dynamic membrane played an essential role in rejecting particulate matter [19]. Figure 4 represent the schematic diagram of dynamic MBR.

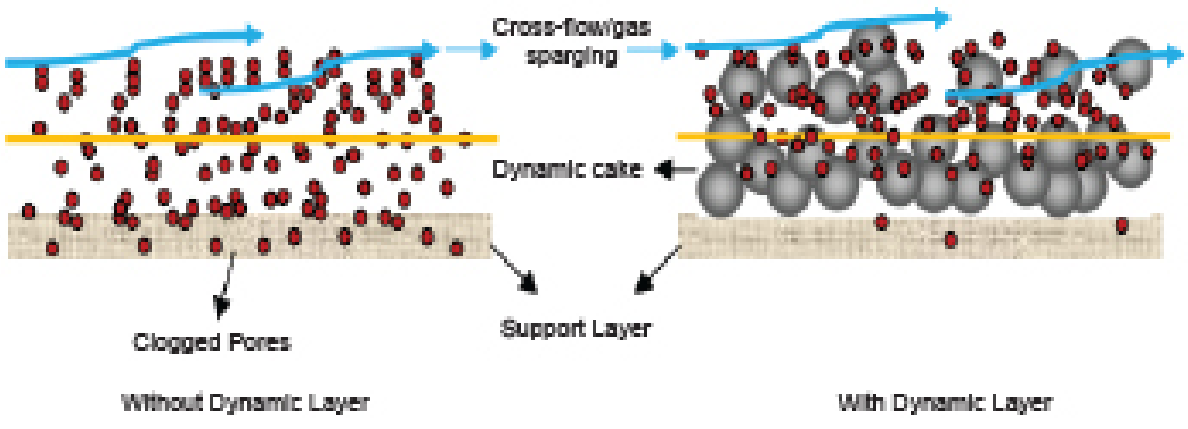

Figure 1: Demonstration of the dynamic cake layer [17].

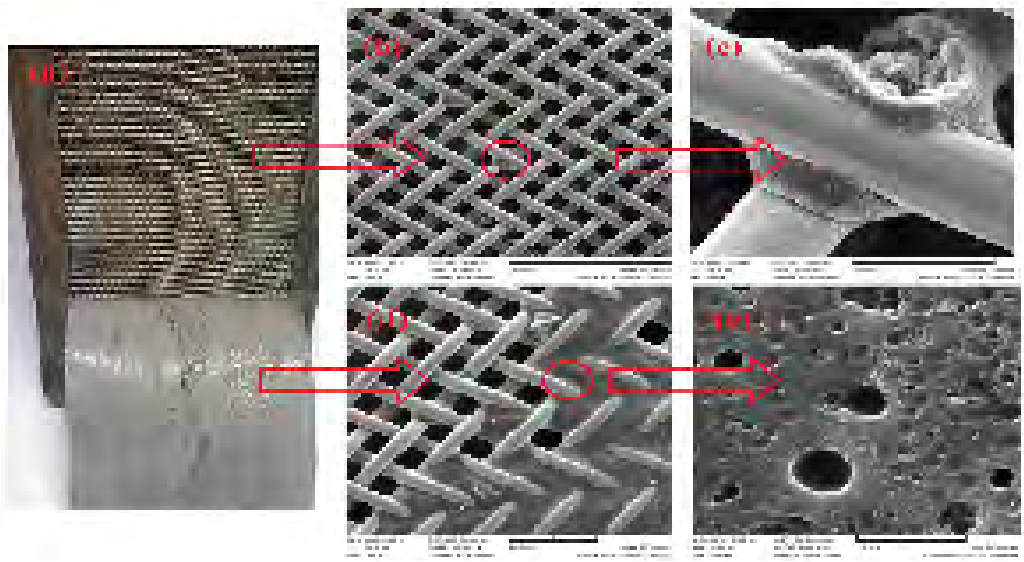

Figure 2: Pictures of stainless steel mesh after backwash: (a) the backwashed support module; (b) the inner support mesh; (c) SEM of the black of the outer support mesh; (e) SEM of the outer support mesh [14].

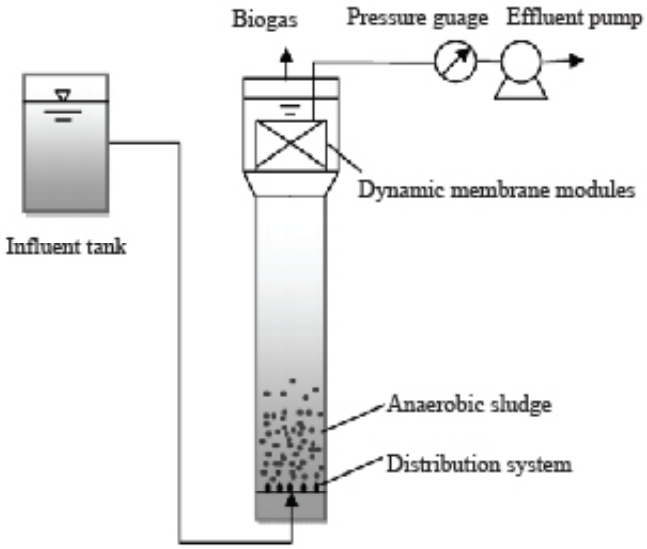

Figure 3: Diagram of AnDMBR [18].

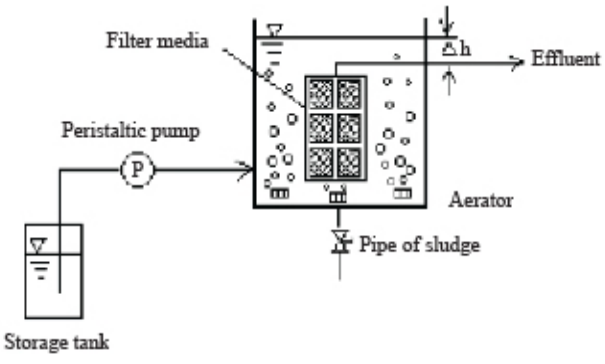

Figure 4: Schematic diagram of the dynamic MBR [19].

Characteristics of bio diatomite dynamic membrane process for municipal wastewater treatment was investigated with a laboratory scale continuous flow device. The experimental results indicate that the BDDM reactor was highly effective in removal of COD, NH_4-N and TN, and exhibited the advantages of good retention capacity for suspended solids, short pre-coating time, high filtration flux and easy backwash [20].

Further studies about the suitable thickness of a powder activated carbon (PAC) as the pre-coated dynamic membrane coupled with a bioreactor municipal wastewater treatment was carried by Ref. [10]. In the study, a pre-coated dynamic membrane was studied carefully. The module consisted of 56-micrometer terylene filter cloth as the support membrane and powder activated carbon as the pre coating agent in the experiment. The pre-coated DM was used in the treatment of municipal wastewater. So from the flux recovery, retention capacity and alleviating membrane fouling, the best thickness of the PAC DM were checked and the result showed that the formation of pre-coated dynamic membrane from powder activated carbon as a support membrane belonged to the cake filtering model. It was found that while the flux of pre-coated dynamic membrane was kept at high value, the operating pressure of the membrane rose to 42 kPa after 43 days of stable operation of the pre coated DMBR [10] from the study; it shows that PAC played a vital role in the formation of a thick membrane layer.

Recently, Ref. [21] carried out a research on the development and permeability of a dynamic membrane for anaerobic wastewater treatment, the study aims to develop anaerobic dynamic membrane for wastewater treatment with the use of large pore size mesh. From the study, it was demonstrated that dynamic membrane can be formed by using a mesh of 200 lm pore size and by applying low cross-flow velocity during the formation. It was then concluded from the experiment that a dynamic membrane for anaerobic wastewater treatment can easily be formed on a mesh with large pore size if suitable operating conditions are applied [21].

Since membrane fouling and the high cost of a membrane is a major problem, Liang et al. [22] described how membrane bioreactors have been employed for municipal and industrial wastewater treatment.

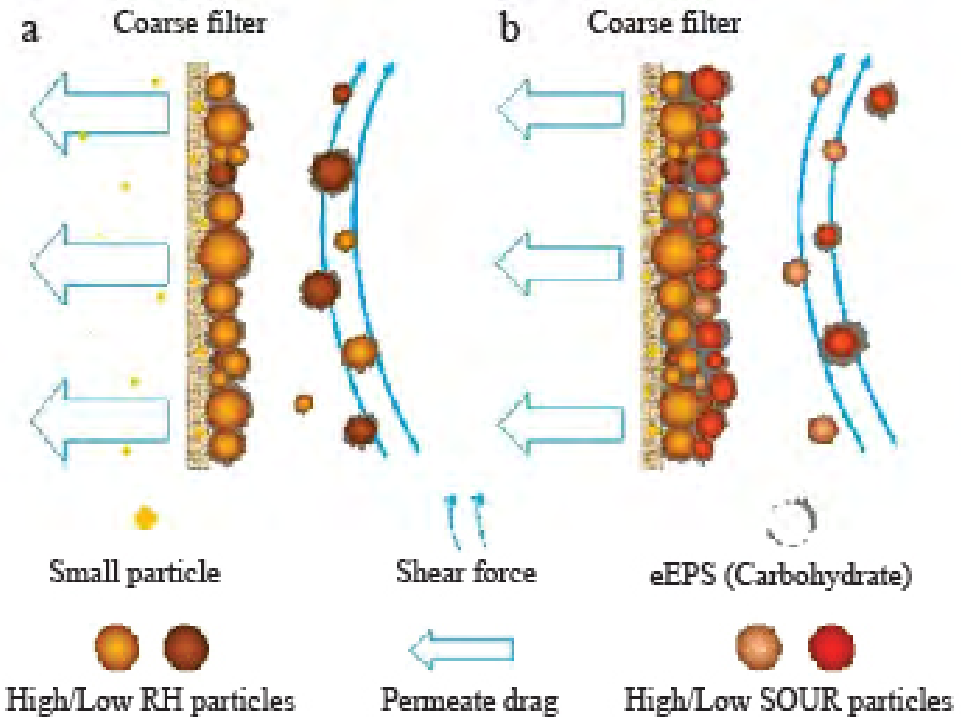

Figure 5: Schematic illustration of the mechanisms underlying formation. (a) Initial rapid fouling (b) of SFDMs developed on coarse pore-materials [22].

They attempted to address the recent issues on membrane fouling by the introduction of DM as the possible solution to membrane fouling; membrane fouling and materials were investigated. From the viewpoint of fouling, reversibility with physical and chemical cleaning, fouling thus consist of removal and irremovable fouling. Membrane fouling can then be classified into three groups which include organic fouling, inorganic fouling, and biofouling [22]. Further investigation on membrane fouling was done. From the study, the effect of sludge properties on the filtration characteristics of a self-forming dynamic membrane (SFDMs) in aerobic bioreactors: Formation time, filtration resistance and fouling propensity were evaluated. The study attempts to highlight the properties of sludge that affect the fouling propensity of self forming dynamic membrane, filtration resistance and formation time [22]. Figure 5 shows the mechanisms underlying formation (a) and initial rapid fouling (b) of SFDMs developed on coarse pore-materials.

Results from experiment show that dynamic membrane with a pre -coated surface of 56 μm pore size terylene filter cloth with powder activated carbon produced a clear effluent quality as compared to the traditional MBR. But the major disadvantage of the process is that material in support of the filtration has to be pre -coated with external materials. On the other hand, the self- forming DM is regarded as the most suitable as it requires the use of substances existing in the liquor to pass through filtration; no external material is required to support the membrane formation [10]. The technology of self-forming dynamic membrane has only presently been researched for its application for aerobic membrane bio reactor AMBRs municipal and industrial wastewater treatment, with a good result. operated aerobic bioreactor fixed with a 100 μm mesh successfully, with the flux between the range of 15-30 $L/m^2 \times h$, a clear effluent with no suspended solid was obtained [7].

Conclusion

Research on DM application has generally been focused on the formation materials of the membrane and the condition suitable for the formation of the membrane. By modifying the two factors mentioned, filtration capability similar to that of RO, MF, UF or nanofiltration membrane could be achieved. Since the application of DM in wastewater or municipal wastewater treatment is still in its infancy, interest should best focused on materials suitable for the formation of the membrane by starting the process with a pre-test to see the best materials needed to construct a good dynamic membrane with high rejection strength.

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