Textile Wastewater Treatment Using Membrane Bioreactor: Opportunities and Challenges in Bangladesh

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Abstract

Due to its inherent benefits over traditional biological treatment, membrane bioreactor (MBR) technology has been increasingly used for the treatment of industrial wastewater. It is a viable solution for the treatment of textile wastewater. MBR treatment of textile wastewater has been examined as a dependable method for the removal of a considerable number of pollutants. The limited adoption of MBR technology in the Bangladeshi textile sector is a result of its high operating and maintenance costs. In this work, the use of aerobic, anaerobic, and hybrid membrane bioreactors (MBR) for textile wastewater treatment, as well as prior research, potential, and problems of MBR processes in Bangladesh, are discussed in terms of textile wastewater treatment. Future research should concentrate on developing new, low-cost membrane materials that are less prone to fouling and need less energy to operate.

Keywords

Membrane bioreactors, Textile wastewater treatment, Membrane technology, Application of MBR and Activated sludge process.

1. Introduction

Utilizing a wide range of various dyes and auxiliary chemicals in a wide range of industrial processes results in the production of wastewater with complicated and highly variable properties, making their treatment particularly challenging (Vandevivere et al. 1998; O'Neill et al. 1999). About 700 thousand to 1 million tons of dyes are produced each year, of which 280 thousand tons (Ali 2010) are released via textile industry effluents, making the textile industry one of the most water-intensive industrial sectors. Thus, one of the most important manufacturing industries that generates a lot of highly polluted and poisonous effluent is the textile industry. According to the World Bank's estimation, the textile sector is responsible for 17–20% of industrial water contamination (Kant 2012).

The azo dyes are one of the most widely used classes of colorants in the textile industry (O'Neill et al. 1999). Physical, chemical, or biological techniques can be used to remove them from wastewater, but biological treatments are typically chosen since they are less expensive and more environmentally responsible (Elisangela et al. 2009; Ranjusha 2010).

The sustainable treatment of textile wastewater has been examined over the past few decades using a variety of treatment systems. Three categories can be used to classify treatment technologies for textile wastewater: processes for separation and concentration, processes for deconstruction and degradation, and processes for exchange (Wang,Hung, Lo andYapijakis 2005). Process variables have a significant impact on the biological treatment of textile effluent (Rai 2005; Pandey, Singh, and Iyengar, 2007). The textile mill's production method, chemical usage, effluent elements, discharge standards, location, capital and operational expenses, land availability, and skill and competence levels all play a role in the choice of a suitable technology type. To meet the final discharge or recycled treated water quality standards, suitable combinations of these technologies are used in full scale treatment systems. In comparison to other traditional treatment technologies, membrane bioreactor (MBR) technology has demonstrated higher performance in the treatment and operation of home and a variety of industrial wastewaters (Lin 2012). MBR has emerged as a desirable wastewater treatment method that generates recycled water of the highest quality. The MBR process has a number of benefits over traditional activated sludge processes, including a small environmental footprint, low maintenance, consistency in final treated water quality independent of sludge conditions in the bioreactor, lower sludge production, and higher removal of nutrients, organic, and persistent organic pollutants.

Treatment of textile wastewater using membrane technologies has been successful. When membranes have been used alone to treat textile wastewater, a train of filtrations has often been used. This includes reverse osmosis (RO), microfiltration (MF), ultrafiltration (UF), and nanofiltration (NF) (Alcaina-Miranda 2009). Membrane bioreactors (MBRs) are used when extremely high-quality effluents are required, such as for water reuse, and combine biological processes (usually activated sludge) with membrane technologies (Van Nieuwenhuijzen, Evenblij, Uijterlindeand Schulting 2008; Meng 2009). Additionally, MBRs have been regarded as the best pretreatment when additional filtration (such as reverse osmosis or nanofiltration) is required (Cornel and Krause 2006).

1.1 Objectives

The goal of this study is to compile the findings, information, and data from recent research studies on the use of MBR technology for the treatment of textile wastewater. To draw some significant conclusions and recommendations, the results will be scrutinized and contrasted.

2. Application of MBR for textile wastewater treatment

Except for the separation of activated sludge and treated wastewater, the MBR principle is comparable to traditional biological wastewater treatment. In the MBR system, this separation is accomplished by membrane filtration, whereas it is accomplished through secondary clarification in the traditional system. Regarding the removal of suspended particles and organic materials, the MBR system offers a high level of treatment.

A second way to divide MBR systems is into two categories: aerobic MBRs and anaerobic MBRs. The aerobic MBR combines an aerobic bioreactor with a membrane filtering unit. Submerged systems have accounted for the majority of aerobic MBRs for municipal wastewater treatment. Side stream systems have often been employed for the aerobic MBR treatment of industrial wastewater (Benitez, Rodríguez andMalaver 1995; Yamamoto and Muang Win 1991).

2.1 Aerobic MBR

Aerobic MBRs are an essential technological alternative for wastewater reuse, since they are extremely compact and efficient systems for separating suspended and colloidal debris and are capable of meeting the highest effluent quality criteria for disinfection and clarifying. One of the most frequently touted advantages of this process over the standard activated sludge procedure is the reduction in sludge generation that follows from operating at high solid retention time (Judd 2010). Aerobic membrane bioreactors (MBRs) are one of the main technologies for achieving sustainability in wastewater treatment via reuse, decentralization, and low energy usage (Fane and Fane2005).

A study on MBR revealed that following aerobic MBR treatment, the COD removal efficiency was 97% and the color removal efficiency was 70% (Badani 2005). Another investigation found that the COD removal rate was 70% and the color removal rate was 87% (Brik 2006). In 2009, Huang et al. researched textile wastewater treatment with MBR technology and reported that MBR had an 85-92% COD removal and a 60-75% color removal rate (Table 1).

Table 1. efficiency of aerobic MBR in textile wastewater treatment

MBR type	Percentage of COD removal	Percentage of color removal	Reference
Aerobic MBR	97	70	Badani 2005
	60-95	87	Brik 2006
	85-92	60-75	Huang et al. 2009
	95	97	Yigit et al. 2009

Hybrid MBR	-	98.3	De Jager, Sheldon and Edwards 2012
	>90-95	>70	Grilli et al. 2011

2.2 Anaerobic MBR

Due to its great advantages over traditional anaerobic treatment and aerobic MBR treatment, anaerobic MBR technology has been considered a potentially desirable wastewater treatment system. The low energy consumption of anaerobic MBR systems is due to the fact that no aeration energy is required for mineralization of organics. It generates less sludge. In addition, anaerobic MBR produces valuable methane as a byproduct. The textile wastewater treatment employing anaerobic MBR was shown to be quite successful for COD and TSS removal, according to studies. However, there was a small amount of total nitrogen and total phosphorus elimination (Ivanovic andLeiknes 2012; Lin et al. 2011). Possibly due to the fact that both total nitrogen and total phosphorus elimination procedures needed anoxic and aerobic zones.

2.3 Hybrid MBR

In recent years, a large number of research projects have been conducted to enhance the decolorization and treatment of textile wastewater employing MBR in conjunction with various physical, chemical, and physical–chemical treatment approaches. Grilli et al. 2011 reported the performance of the combination of MBR (with UF membrane) and NF for the treatment of textile wastewater. They discovered that MBR alone eliminated 90–95% of COD and 70% of color which was further reduced after a post-treatment with NF. (Table 1).

In 2012, De Jager et al. studied both nanofiltration and reverse osmosis as MBR effluent post-treatments. It was discovered that MBR alone eliminated 28.6% of color, however the combination of MBR and NF considerably removed up to 98.0% of color (Table 1).

3. Activated sludge process Vs MBR

A study was conducted by Yang et al. 2020 to compare the efficiency of a membrane bioreactor to conventional activated sludge process. It was found that MBR had the best performance when it comes to color, COD and TSS (total suspended solid) removal.The average biomass concentrations in the conventional activated sludge and MBR during the study were 3 g/L and 2.3 g/L, respectively. The initial hydraulic retention time for both systems was two days, and the first organic loading rate (OLR) was 1 kg COD/m3.

The color of the inlet ranged from 400 to 1500 mg Pt-co/L. The average color removal efficiency for the activated sludge process was 55% and for the MBR system it was 80%. MBR was substantially more effective than CAS at removing color under identical operating circumstances.

The COD of the influent remained around 2000 mg/L. The average COD effluent of the CAS process was 350 mg/L, with an average COD removal efficiency of 83%. The average COD concentration of MBR effluent was 170 mg/L, and COD removal efficiency was 91%. This result is supported by previous research (Lorena, Martì and Roberto2011).

The average TSS removal effectiveness of the activated sludge was 66%, and the MBR system was 99.9%. The results demonstrated that the MBR process is superior to the CAS procedure in terms of TSS reduction without the use of tertiary treatment.

4. MBR in the textile industry of Bangladesh

Research and commercial uses of Membrane bioreactor (MBR) technology are expanding around the world (Pardey, Sapkal and Sapkal 2017). In Bangladesh, there has been an explosion of textile, tanning, and other manufacturing businesses during the past several decades. Consequently, these sectors create a substantial quantity of waste water. In spite of the Bangladeshi government's zero-discharge policy, however, these businesses seldom adhere to the norms and regulations they are required to go by, resulting in negative environmental impacts. Membrane bioreactor applications in the textile sector are uncommon. In Bangladesh, research on membrane bioreactors is similarly uncommon.

Table 2. Water quality parameter of MBR (in Bangladesh) and traditional ETP

Quality parameter	Unit	Standard limit	Influent	Effluent (MBR)	Effluent (Traditional ETP)
TDS	mg/l	2100	3200-4800	2200-2600	2400-3300
COD	mg/l	200	<2500	<200	<800
BOD	mg/l	50	400	<80	<250

Shahjalal University of Science and Technology researchers built an MBR (Figure 1) (Saha et al. 2014). It was constructed from locally accessible PMMA panels, stainless steel, and aluminum profiles. The aeration was given by a compressor at 0.2 bar pressure. The reactor was outfitted with a Polyvinylidene fluoride plate-and-frame microfiltration membrane module (PVDF). The average pore size was around 0.2 µm, and the overall membrane surface area was 0.25 m^2.

Figure 1. Schematic diagram of the MBR designed by Saha et al.

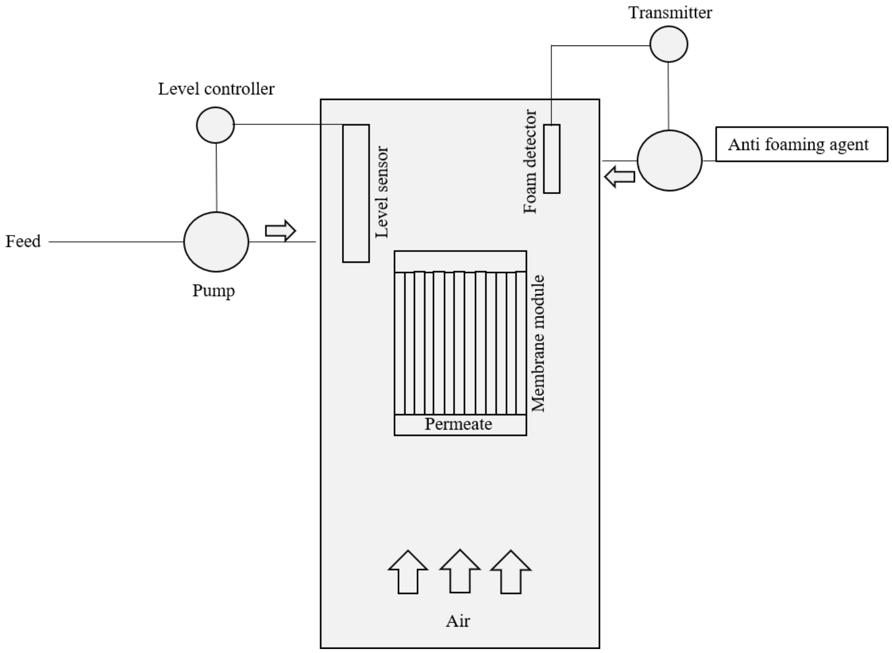

Table 2 shows that the COD in the MBR output was less than 200 mg/L, while the COD in the influent was close to 2,500 mg/L. The BOD removal was acceptable as well. The BOD was lowered by MBR from 400 mg/L to 80 mg/L. In terms of total dissolved solids, membrane bioreactor effluent contained 2,200 to 2,600 mg/L. Despite the fact that this outcome is more promising than traditional ETP, the TDS level is still over the national standard.

5. Opportunities and challenges of MBR in Bangladesh

End customers are becoming increasingly aware of environmental sustainability. Thus, the number of initiatives in the textile business focused on environmental sustainability is expanding daily. This industry represents great hazards to the environment. To address environmental risks, the government has enacted stringent regulations and legislation regarding wastewater treatment and disposal. The regulation requires that all companies producing Red category wastewater, including textile dyeing operations, must treat their effluent before discharging it. Additionally, modern purchasers want their supplier base to be environmentally friendly.

When it comes to wastewater treatment technologies, MBRs are becoming increasingly popular for water and wastewater applications that demand high-quality treated water or have limited space. Membrane bioreactors have several benefits over alternative wastewater treatment methods. Due to the tiny pore size (0.5 m) of the membrane, the treated effluent has very high clarity and a dramatically reduced pathogen content in comparison to the CAS method. MBR procedures provide effluent that is sufficiently cleared and disinfected to be released to sensitive receiving bodies or recovered for purposes such as urban irrigation, utilities, and toilet flushing (Wisniewski 2007). It is also of sufficient grade for direct input into a reverse osmosis process. The plant footprint is affected by the retention of solids in the reactor and the increase in SRT to create larger biomass solids concentrations. Due to the increasing concentrations, the same total mass of solids is stored in a smaller container, resulting in a smaller footprint.

Higher capital and operational expenses than traditional systems for the same throughput are the greatest obstacle for the MBR technology in the Bangladeshi textile sector. Membrane cleaning and fouling management are included in operating and maintenance expenses, as is eventual membrane replacement (Judd 2008). Due to the requirement for air scouring to prevent bacterial development on the membranes, energy expenditures are also increased. These expenses discourage investors from implementing this technology in their plants.

6. Conclusion

Application of MBR to treat textile wastewater is an emerging technology that requires research on interactions between membrane materials and dyes, optimization of the MBR in terms of SRT, HRT, and mode of operation in order to reduce cost and improve effectiveness. Although a considerable number of research studies on evaluating the effectiveness of MBR technology for textile wastewater have been completed globally, in Bangladesh, the number is quite low. MBR is a promising alternative for textile wastewater treatment. The effectiveness of MBR in eliminating pollutants is contingent on its operating circumstances. Few studies have examined the optimization of the operational parameters of the MBR for the removal of pollutants from textile wastewater. Optimization is closely tied to operating and maintenance expenses, which is one of the primary reasons why MBRs are uncommon in Bangladesh. It is therefore possible to adjust the operational parameters in order to reduce the high operation and maintenance costs. Innovative, low-cost membrane materials that are less susceptible to fouling and use less energy to function should be the focus of future research.

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