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MBR technology for textile wastewater treatment: First experience in Bangladesh

Pradip Saha [*1a], Md. Zakir Hossain [1a], Md. Salatul I. Mozumder [1b], Md. Tamez Uddin [1b], Md. Akhtarul Islam [1c], Jan Hoinkis [2c], Shamim A. Deowan [2d], Enrico Drioli [3c] and Alberto Figoli [3c]

[1] *ShahJalal University of Science & Technology (SUST), Sylhet-3114, Bangladesh*
[2] *University of Applied Sciences Karlsruhe, Moltkestr. 30, 76133 Karlsruhe, Germany*
[3] *Institute on Membrane Technology (ITM-CNR), 87030 Rende (CS), Italy*

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Abstract. For the first time in Bangladesh, a bench scale membrane bioreactor (MBR) unit was tested in treating a textile wastewater in the industry premises of EOS Textile Mills LTD, Dhaka for three months. The performance of the unit was compared with that of the conventional activated sludge treatment plant, which is in operation in the same premises. The COD and BOD removal efficiency of the MBR unit reached to around 90% and 80% respectively in 20 days whereas the removal efficiency of the conventional treatment plant was as low as 40-50% and 38-40% respectively. The outlet COD and the BOD level for the MBR unit remained stable in spite of the fluctuation in the feed value, while the conventional effluent treatment plant (ETP) failed to keep any stabilized level. The performance of the MBR unit was much superior to that of the functional ETP and the water treated by the MBR system can meet disposal standard.

Keywords: COD; industrial wastewater; membrane bioreactor; MBR; textile industry

1. Introduction

The textile and apparel industry in Bangladesh occupies a prominent position within the country‘s industrial k structure reported by anonymous (2003), contributing 10.5% of the country’s GDP in the 2006/07 fiscal year presented in anonymous (2012), and in a report, Bangladesh Bank (2012) mention that during July-January, 2010-2011 more than 77% of the total income from industrial products is earned from the export of woven garments and nitwear. Dhaka City State of Environment Report (2005) studied that most of the textile industries are located at or

∗Corresponding author, Assistant Professor, E-mail: pradip-cep@sust.edu
[a] Assistant Professor, E-mail: mzhbd1979@gmail.com
[b] Professor, E-mail: salatulislam@yahoo.co.in; mtuddin_cep@yahoo.com
[c] Professor, E-mail: mislam@sust.edu; jan.hoinkis@hs-karlsruhe.de; e.drioli@itm.cnr.it; a.figoli@itm.cnr.it
[d] Ph.D. Student, E-mail: sadeowan@gmail.com

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around Dhaka city and they use ground water in various stages of textile processing. The groundwater level declines at a rate of as high as > 1 m/yr. in urban and peri-urban areas around Dhaka city and would decline 9-25 m by the year 2015 and 18-40 m by the year 2025 (Shamsudduha *et al*. 2009, Sarkara and Alia 2009). In addition, textile industry is one of the most chemically intensive industries on the earth and the major polluter of potable water. It generates huge quantities of waste chemical substances including dyes as constituents of wastewater (Verma *et al*. 2012). In these circumstances, wastewater reclamation and reuse have become essential for sustainable development of textile industries. Increasingly stringent environmental legislation and generally enhanced intensity, efficiency, and diversity of treatment technologies have made the reuse of water more viable in many industrial processes. Whether applied in the domestic or industrial environment, membrane processes play a key role in water recycling since they can produce water of a reliable quality (Hoinkis *et al*. 2012). Recovery and reuse of industrial effluents is generally governed almost entirely by economics, which may be driven by regulations. Among the membrane techniques, Membrane Bioreactors (MBRs) will be an essential part of advancing such water sustainability, because this technology encourages water reuse and opens up opportunities for decentralized treatment. MBR is a combination of bioreactor and membrane technology (microfiltration, ultrafiltration). The MBR systems can replace conventional treatment and combine clarification, aeration and filtration into a single unit in a simple and cost-effective way that reduces capital and operational costs. Hoinkis and Panten (2008) reported that the result is consistent production, by MBRs, of high quality effluent suitable for any discharge or re-uses. The MBRs systems are increasingly being specified as the best available technology for virtually all wastewater treatment applications- from green field plants to retrofits to water reclamation projects. They offer several operational and economic advantages over conventional wastewater treatment plants including extremely compact footprints, simplified operation and consistently high quality effluent – all for a satisfactory life cycle cost, describe by Abegglen and Siegrist (2006). In several studies by Hoinkis, and Panten (2008), Abegglen and Siegrist (2006) and Cicek (2002) contented that MBRs system has been tested in the treatment of effluent from food and beverage, chemical, petrochemical, pharmaceutical and cosmetics, and textile industries as well as from laundries, and the treated water quality has been found to meet the required standard with respect to the chemical oxygen demand (COD), biochemical oxygen demand (BOD), suspended solids (SS), and turbidity.

The purpose of this work is 1) to develop a technical MBR unit which will serve as a mobile wastewater treatment unit conducting bench scale field trial in a given industrial premise, and 2) to compare the performance of the unit to that of the biological unit, which is in operation in the same premise. Thus the feed water quality and the atmospheric conditions are maintained identical for both the MBR and the conventional unit. The MBR unit has been designed based on the preceding experiences at the University of Applied Sciences Karlsruhe, Germany in treating laundry and textile effluents (Bucheister *et al*. 2006, Fondjing 2004). The technology has been adapted to the needs of developing countries like Bangladesh and it can easily be replicated by local producers. A textile company near Dhaka, EOS Textile Mills LTD, has been selected as spot in order to gain initial experience with this kind of technology which, to the authors‘ knowledge, has been introduced for the first time in Bangladesh in the form of practical application. The quality of the water treated by the MBR unit is found to be much superior to that done by the conventional activated sludge plant operating in the industry. Also the MBR effluent quality remains stable in spite of the fluctuation of the feed quality, while that from the conventional unit fails.

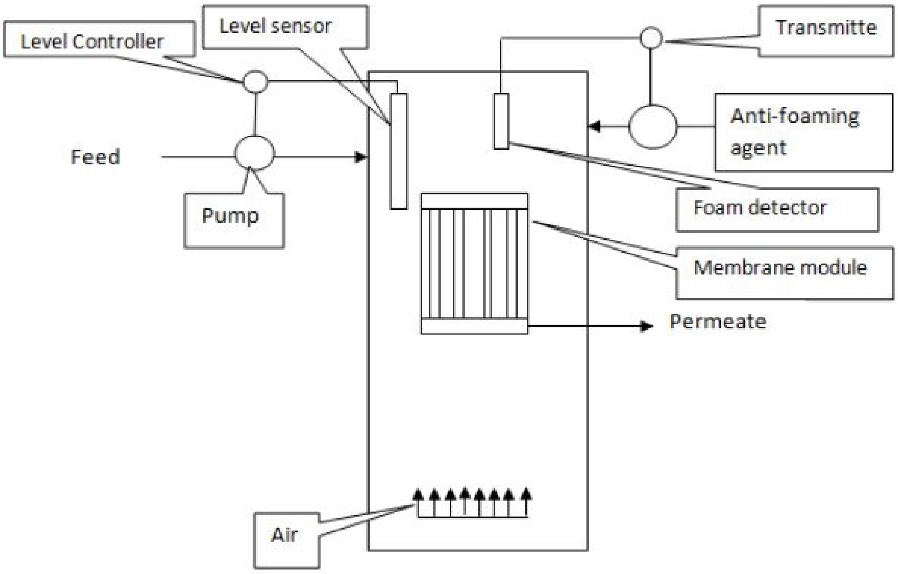

Fig. 1 Schematic view of the MBR unit

2. Materials and methods

2.1 Design and assembly of a pilot scale MBR

The MBR was designed and manufactured at the Center for Environmental Process Engineering, SUST. The schematic view of the setup is presented in Fig. 1. It was fabricated with locally available Plexiglas (PMMA) panels, stainless steel and aluminum profiles. The working volume of the reactor was approximately 200 L with around 125 cm in length, 40 cm in width, and 40 cm in height. A diffuser for aeration was placed at the bottom part of the reactor. The aeration was provided with a compressor at a pressure of 0.2 bar, measured with a pressure gauge. The reactor had been equipped with a plate and frame type microfiltration membrane module, made of Polyvinylidene fluoride (PVDF), supplied by a German company 'A3 Water Solutions GmbH'. The average pore size was around 0.2 μm; the total membrane area was 0.25 m^2. The water level in the reactor was always maintained at a constant level with a capacity level sensor in a by-pass tube sideward of the reactor. An anti-foaming sensor was designed and installed to dose the anti-foaming agent in the reactor in case of foaming.

2.2 Operation and monitoring of the performance

At first the MBR reactor was filled up with the activated sludge from the Effluent Treatment Plant (ETP) of EOS for the quick and proper growth of bacteria. Then the MBR unit was continuously fed with the textile wastewater from the collection tank of the EOS (from which the ETP was also fed with). The MBR unit was running continuously and the samples were collected every 2-3 days to check the COD (mg/l) and the BOD (mg/l) at the inlet and outlet of both the MBR unit and the ETP. The water flux (L/m^2.h) through the membrane, temperature, pH and the electrical conductivity had also been monitored regularly. The mixed liquor suspended solid (MLSS), total solid (TS) and the total dissolved (TDS) were measured from time to time. The reactor was operated continuously for two months. All the water quality parameters were determined in the laboratory of the EOS following standard methods.

3. Results and discussion

3.1 COD Removal

The COD is often measured as a rapid indicator of organic pollutant in water. It is normally measured in both municipal and industrial wastewater treatment plants and gives an indication of the efficiency of the treatment process. Figs. 2-3 represent the performance of the MBR as compared to the conventional ETP with respect to COD. As seen from the Fig. 2, for the same COD at the feed level, the quality of water at the MBR exit is much better than that in the ETP exit.

The COD values in the MBR effluent rapidly falls to below 200 mg/L satisfying the disposal standard imposed by the Department of Environment, Bangladesh (Ministry of Environment and Forest, Bangladesh 2008). The COD at the exit of the conventional treatment plant, however, remains higher than 700 mg/L for the same feed COD value of around 1800-2500 mg/L. The COD removal efficiency (defined as the decrease in the COD per unit COD fed to the reactor) reaches to 90% in 20 days, whereas the efficiency of the conventional treatment plant is in the range of 40-60%. The MBR efficiency, soon in Fig. 3, remains stable in spite of the COD variation in the feed. The COD at the ETP-exit, however, more or less follows the fluctuation in the feed values. Similar stabilization of the COD level in the MBR with fluctuation in the feed level was observed also by Hoinkis and Panten (2008) and Huang *et al.* (2009).

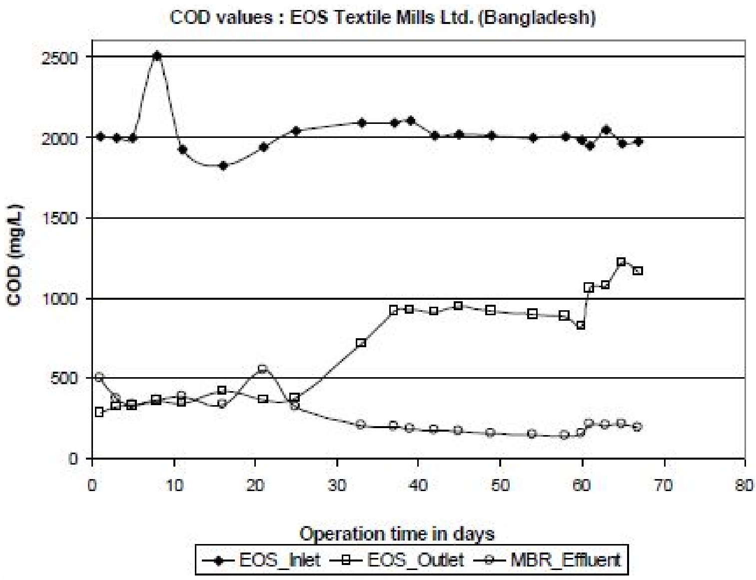

Fig. 2 COD level at the entrance and the exit of the ETP and the MBR unit

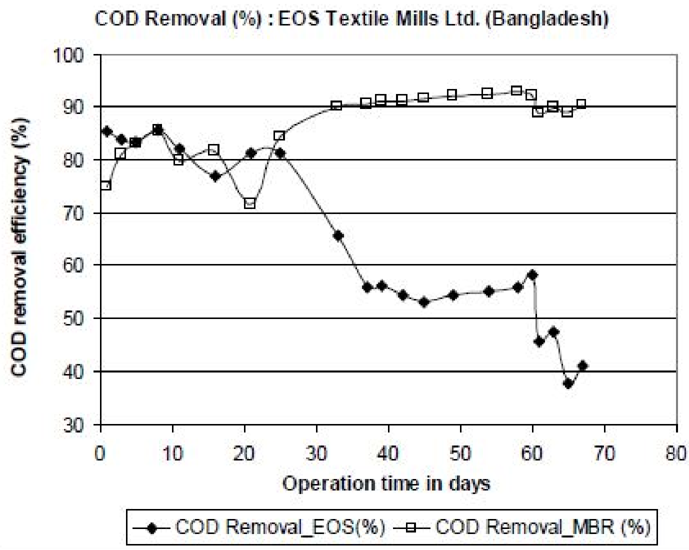

Fig. 3 COD removal efficiency at the EOS ETP unit and the MBR unit

3.2 BOD removal

The Biological Oxygen Demand (BOD) indicates the biodegradability of the organic materials in wastewater. From the Fig. 4 the inlet BOD of both the MBR unit and the conventional treatment plant was around 400 mg/L, but the BOD of the MBR outlet was around 80 mg/L and that of the ETP was around 250 mg/l. With respect to the parameter BOD^5 also, the performance of the MBR is much better than that of the ETP.

3.3 MLSS level

The MLSS level in the MBR unit was around 1.3 g/L at the start and did not vary appreciably throughout the experiment. This value is much lower than the MLSS level of 10-20 g/L typically maintained in MBR systems. The MLSS level in the MBR system under investigation is comparable to that in conventional activated sludge tanks, where the level is lower than 5 g/L. But as seen in Figs. 2 and 4, with this low MLSS level in the MBR unit, the disposal standard of the effluent could be maintained with respect to the COD and BOD.

3.4 Flux variation through the membrane module

Flux is an important parameter to characterize the membrane performances as the efficiency of the plant depends on this parameter. The MBR operated under gravity flow. The liquid head above the membranes (ca. 0.3 water column) acts as the driving force for the flow of water through the membrane, while the activated sludge is retained at the membrane surface. The accumulation of the sludge at the membrane surface causes gradual increase in the resistance to the water flow and sometimes clogging of the membrane pores. The aeration in the reactor is arranged in such a manner that along with the supply of oxygen to the microorganism in the system, it generates a

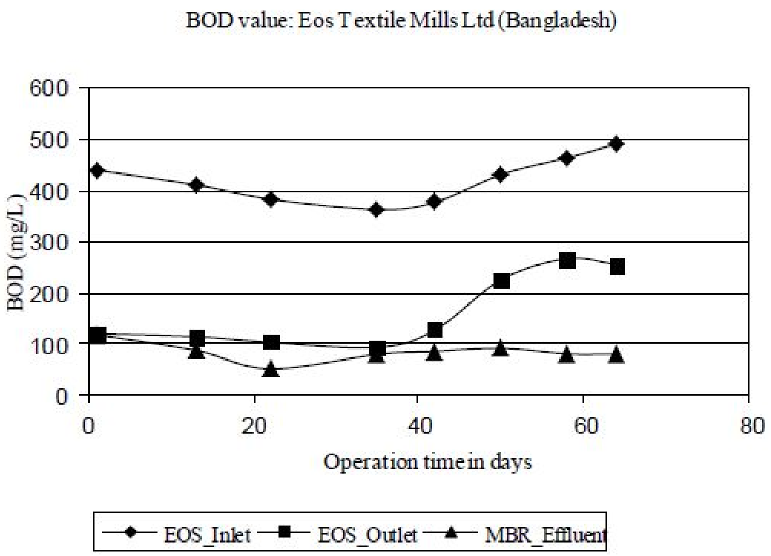

Fig. 4 BOD level at the entrance and the exit of the ETP and the MBR

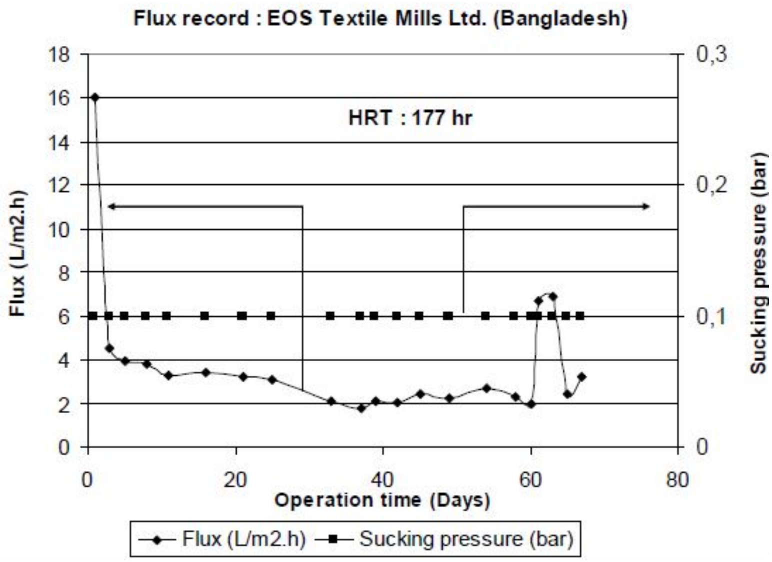

Fig. 5 Permeate flux through the MBR unit during field operation

cross flow along the membrane-surface preventing or reducing sludge accumulation at the membrane surface and the clogging of the pores. But still the flux through an operating membrane deteriorates rapidly. Fig. 5 shows that the flux drastically reduced from its initial value of 16 $L/m^2.h$ to around 2 $L/m^2.h$. After 60 days of operation the membrane module was cleaned with 1% H_2O_2 and the flux increased to ca. 7 $L/m^2.h$, but retained such value for the next 3 days only and

Table 1 Summary of performance data

Parameter	Unit	National Standard*	Feed at MBR/ETP inlet	MBR outlet	ETP outlet
Temperature	°C	40-45	45-50	30-35	30-38
pH	-	6-9	7-10	7-9	8-9
Electrical conductivity	μs/cm	1200	900-1100	400-700	400-700
TDS	mg/l	2100	3200-4800	2200-2600	2400-3300
COD	mg/l	200	< 2500	.< 200	< 800
BOD^5	mg/l	50	400	< 80	< 250

*National Standards – Waste Discharge Quality Standards for Industrial water at the Discharge Point-Inland surface water (Department of Environment, Government of Bangladesh 2008)

finally dropped down to the previous stable level. During further operation, from time to time the membrane was cleaned with 1% H_2O_2 and this resulted in an increase the flux of the process for short time, but again fell to the limiting value of 2 L/m^2.h. Obviously, with present configuration of the set up and under the applied operating condition, the flux level is stabilized to 2 L/m^2.h, and this value is to be taken as membrane flux for scale up. Definitely, more study is required to achieve optimal configuration of the set up and the optimal operating condition ensuring higher flux. In addition, further observation is essential for study the economy of scale, which does not take into account in this study.

The performance indicators of the MBR units as compared to that of the ETP for the period of three months (December 2006 to February 2007) have been summarized in Table 1.

As seen from the Table, the performance of the MBR is much better that that of the ETP operating under the similar environmental conditions. With respect to the COD and BOD, the effluent from the MBR meets the disposal standard, whereas that from the existing and functional ETP does not. The TS and the TDS level have been reduced more in the MBR, but still they are bit higher than the permissible limit set by Ministry of Environment and Forest, Bangladesh (2008). The conductivity of the effluent meets the disposal standard, but seems too high to be recycled and reused as process water. This is reasonable as the MBR-membrane does not retain electrolytes used in the laundry. For reuse, a portion of the treated water from the MBR system may undergo further treatment though nanofiltration or reverse osmosis, and then mixed with the remaining portion of the MBR effluent and the conductivity level for process water could be maintained. Despite the cost of the membranes has come down considerably and their life time has increased the membrane invest costs are still a challenge particularly for the submerged MBR systems. The operation costs need also to be reduced. Optimisation of the aeration is required for the submerged systems as air in excess of the biodegradation requirements has to be supplied to reduce membrane fouling.

4. Conclusions

The COD and BOD removal efficiency of the small scale MBR in EOS Textile Mills Ltd. is impressive compared to the efficiency of the conventional ETP in the factory. The MBR system takes around 20 days for the maturation of the system. This technique can provide excellent quality suitable for non-potable reuse in a decentralized way with minimal additional treatment.

The treated water could be reused for industrial purpose. But due to its flexibility and modularity MBR technology offers a bright future for wastewater treatment and reuse in a decentralized way with very good opportunities within the water market. This technology can be adapted to the situation in Bangladesh in wastewater treatment sector especially in textile industry, and other industries like food stuff, dairy, tannery and pharmaceutical industry can also apply this technology in near future.

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