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Water filter-based MBR unit in laundry effluent treatment

M A Islam*, S M Muhtad, A Anwar, M M Islam, M R Amin, M Ar Islam & A K M A Haque
Center for Environmental Process Engineering, Department of Chemical Engineering and Polymer Science,
Shahjalal University of Science and Technology (SUST), Sylhet-3114, Bangladesh

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An aerobic membrane bioreactor (MBR) system has been equipped with low cost water filter units available in local market and tested as a bench-scale unit in a medium size laundry. The purpose of the study is to verify their potentiality for application in MBR systems as an alternative to polymer membrane modules. The performance of the system is evaluated in terms of flux recovery and COD level of the treated water. Cleaning operation is performed by mechanical rubbing/brushing and backflushing. In each operational cycle, the flux is found to deteriorate gradually due to fouling. Mechanical rubbing/brushing results in partial elimination of the fouling and thus partial recovery of the flux, while backflushing to remove the fouling causes internal damage to the filters. Fouling leads to an improvement in the COD removal. It is concluded that the filter units, if modified, could be used in MBR systems, and success of low cost filter-based MBR system would inspire countries with cheap labor to build wastewater treatment plants with their own capacities.

Keywords: Laundry wastewater, Membrane bioreactor, Sintered clay filter, Wastewater treatment, Water filter

The application of MBRs in the treatment of industrial wastewater has been fairly rapidly increasing worldwide in recent years[1-3]. Due to the small foot-print of the MBRs, it seems that they will be the appropriate and attractive solution of wastewater treatment in densely populated countries. The capital investment for the MBR-based treatment plants, however, is very high for the standard of developing countries, and the membrane module itself claims around 50% of the total capital cost for the plants. The MBR technology could also be applied for wastewater treatment in the developing countries provided the conventional membrane module is replaced by a low cost filtration unit readily available or easily accessible in these countries[4]. Besides polymer membrane modules, other elements such as pumps and membrane clogging contribute much to the cost of the MBR operation. Thus, for application in the treatment of wastewater in the developing countries, the MBRs have to meet partially or totally three requirements, namely (i) to run with inexpensive membrane module, (ii) to use hydraulic pressure difference between the water level at the reactor and that at the effluent port, and (iii) to ensure insignificant clogging and long life time.

In an effort to reduce the cost of MBR-application, some investigators[5-11] tested mesh filters, and some[12-16] tested nonwovens as replacement to polymer membranes in MBR units. These filters are cheap and could operate at low hydraulic pressure difference. In recent years, a specific type of filter elements (some version of sintered clay filters) has over-flooded Bangladesh and Indian market, and these filters are successfully used for the treatment of household drinking water. The aim of the present work is: (i) to develop a low cost MBR unit equipped with conventional water-filters as the separation units and (ii) to follow the flux behavior and the overall performances of the MBR in treating an industrial wastewater. For the purpose, locally available conventional water-filters have been installed in a bioreactor and tested in a local laundry. It is found that the bioreactor provided suitable environment for the treatment of wastewater and these filters have the potentiality to be used in MBR systems. But to achieve sustainable performance from these filters in MBR systems, both the method of preparation and the recipe of the composition must be modified to provide them adequate mechanical strength and suitable structure.

Experimental Procedure

Filter units

The filter units used in this study are known in the local market as Madhabpur Filters (MF) according to

*Corresponding author.
E-mail: islamsust@yahoo.com

the name of the locality, where the local potters manufacture them. They are manufactured basically from a composition of red clay, rice husk and sand in the ratio of 3:2:1 (as disclosed by the potters). They are dried in the sun for 2-3 days and then burnt in an oven at a temperature of 500-600°C. The filters have the shape of intersected cone [bottom diameter 10 cm, top diameter 9 cm and the slant height (inclined distance) 17.50 cm]. There is a channel inside the filter with a diameter of 2 cm along the filter axis and closed at the top end. This channel collects the filtrate. The exposed surface area per unit filter is the sum of area of the curved surface and that of the upper circular section, and is equal to 5.9×10^{-2} m^2/filter unit. The permeability of the filter elements varies in the range of $(1.3\text{-}2.5)\times10^{-9}$ m/s.Pa. Neither the composition nor the drying and burning process is maintained strictly. The outer surface of the filter elements are very rough (resembling to abrasive material), making it easy susceptible to fouling. Powder masses are easily released from the surface at mild rubbing. For the present study, a set of three filters units were installed in the MBR named 'SUST Bioreactor (STBR)'.

Object of treatment

MBR systems are applied in the treatment of wastewater from various industries[17,18]. For this study, a laundry wastewater was selected. The criterion of selection was basically not so scientific and technological, rather easy access to the spot and conditions for regular control of the test system. But still the laundry water is a good choice for testing the new MBR system, as the commercial laundries are disposing relatively high quantities of wastewater, and can be regarded as high process water intensive factories. Some authors[19,20] have already reported experimental results of the application of MBR system (with polymer membrane modules) in the treatment of laundry wastewater, and some comparison could be made between the performances of the MBR with polymer membrane modules and the STBR under study.

STBR is tested in form of a bench-scale experiment in a washing industry called 'Rupoz Cleaners' (a medium size laundry in Sylhet, Bangladesh, with a total capacity of around 50,000 L of water consumption per day and operating for 6 days a week) for about 4 months (with several breaks due to maintenance problems). The STBR unit was fed with the final effluent of the laundry with the COD of around 2500 mg/L, pH 9~11 and temperature 28~35°C.

SUST Bioreactor set-up and its principle of operation and control

A schematic diagram of the STBR is shown in Fig. 1. This is a two-chambered aerobic bioreactor consisting of two cylindrical plastic tanks (Reactors 1 and 2). The upper tank is with inner diameter 34 cm, geometrical height 62 cm, effective height 50 cm and the working volume 45 L. The corresponding parameters for the lower tank are 40 cm, 97 cm, 84 cm and 110 L. The lower tank is equipped with three MF units constituting a total filtration area of 0.18 m^2. Both the chambers are aerated continuously to maintain the required oxygen concentration in the system. The lower chamber equipped with the filter units is aerated more intensively than the upper one. The MLSS level in the upper and the lower tank is 3.3 and 3.5 g/L respectively. Two tanks are used instead of one large to ensure uniform aeration and to provide better cross-flow condition around the filters.

The wastewater is fed to the upper chamber. The biodegradation process takes place successively in both the chambers as the water passes from the upper to the lower chamber and finally filters out of the system. The filtration system works under the suction pressure of 0.01 MPa. From time to time, the excess sludge can be discharged from the tanks through the discharge pipe, which may be disposed of by liquid injection to agriculture land.

Operation and cleaning cycles of the STBR

Upon observation of the flux-deterioration and recovery trend after cleaning in some orientation tests, the test method for the STBR units was finalized as follows.

The working cycle consisted of two sub-cycles, namely operational and cleaning. The operational sub-cycle continued for 20 h followed by cleaning cycle (usually around 20-30 min). In this cycle the filter

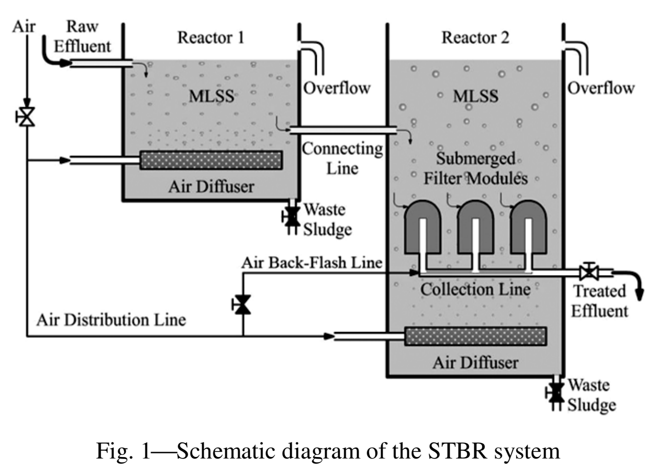

Fig. 1—Schematic diagram of the STBR system

units were cleaned by gentle brushing and then rinsed with water. Then they were returned to the reactor and the next working cycles began. After the completion for the fifth operating sub-cycle, the filter units were subjected to a moderate backflushing for 5-6 min. Then the working cycles were repeated with the mechanical cleaning again. Thus, two groups of data were obtained, namely (i) the flux data before backflushing and (ii) the flux data after backflushing. The sampling for COD was done in 11-12 h of each operational cycle.

Control of the performance indicators

The performances have been evaluated by two parameters viz. (i) the water flux at a suction pressure of 0.01 MPa and (ii) the COD of the treated water. The COD was measured by an open reflux method and its removal efficiency R was calculated by the following formula:

$$R = 1 - \mathrm{COD}_p / \mathrm{COD}_f \qquad \ldots (1)$$

where subscripts p and f represent the permeate and the feed respectively. The flux J was calculated by the following formula:

$$J = V / (A.t) \qquad \ldots (2)$$

where V is the volume of water collected for the time t; and A the total exposed surface of the filter elements.

Results and Discussion

Flux recovery of STBR with gentle mechanical cleaning

The average value of the initial flux of five batches (each consisting of three MF units) is calculated to be in the range 47-81 L.m^{-2}.h^{-1}. Such variation is expected for the filter units produced in cottage industries, where the recipe and the production methods are not maintained strictly. The flux recovery data of a single batch in the STBR is presented in Fig. 2.

The flux deteriorates very rapidly for an operational period of as short as 20 h only. The cleaning of the filter units with brushing and rinsing with water at the end of each operational cycle improves the flux at the beginning, but it does not fully recover the initial flux of the previous cycle. During cleaning, it is clearly seen that the filter surface is fouled, but it can't be ascertained to what depth below the outer surface the sludge has penetrated into. The rapid fouling is attributed to the very rough surface of the filter on which the sludge easily adheres to. This is the main disadvantage of these filters. The COD of the water permeated through the filter units after treatment in STBR is presented in Fig. 3.

The COD-removal efficiency of the treated water has been gradually improving with the increasing working cycle. The permeate looks bit turbid in the initial cycles, which becomes clearer and clearer in the succeeding cycles. Initial turbidity is attributed to the leakage of some microorganism through the virgin filters. Obviously, the filter contains large pores permitting some microorganism to pass through. In fact, these filters are designed to treat bacteria-free underground water contaminated with iron and not to

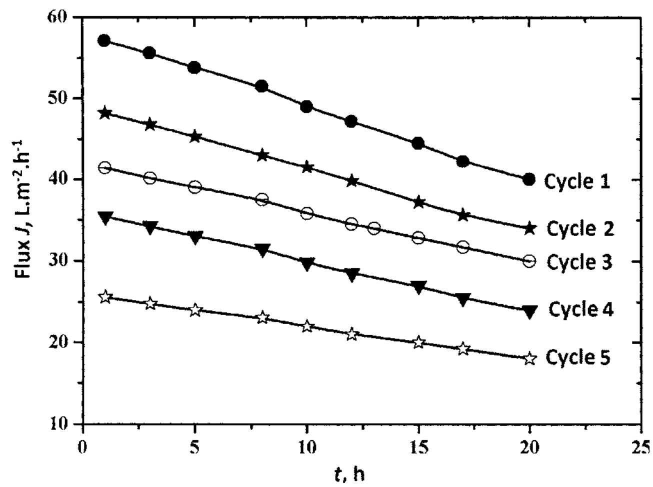

Fig. 2—Flux J *vs* operational time t

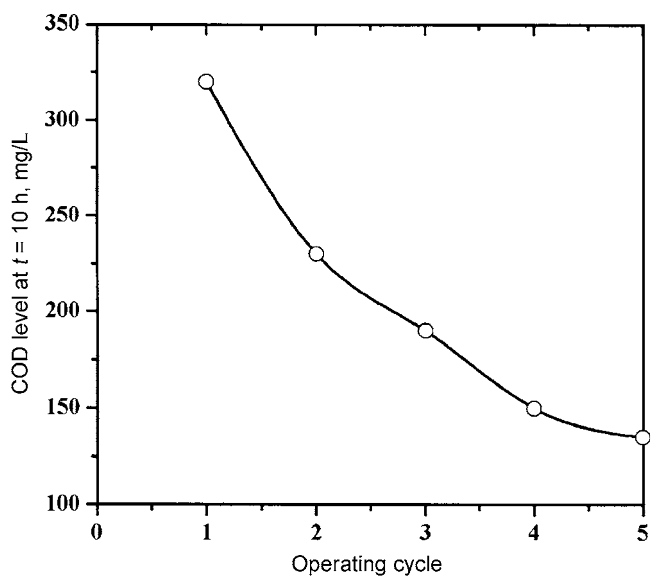

Fig. 3—The COD of the water treated in the STBR equipped with MF units

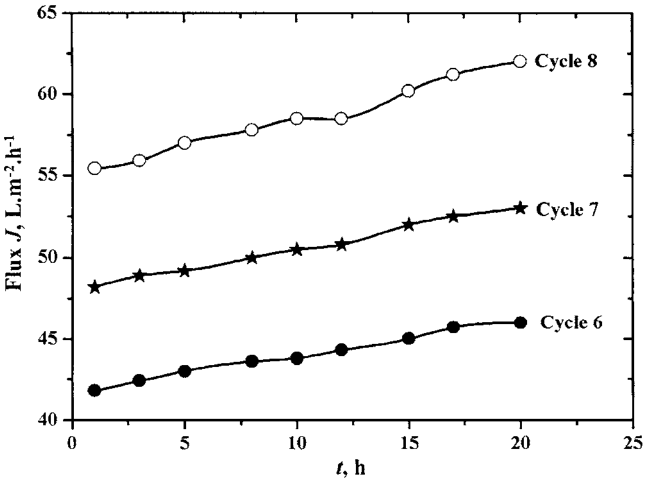

Fig. 4— Flux J *vs* operational time t through the MF units installed in STBR

treat surface water which contains bacteria. Accumulation of sludge on the filter surface prevents further leakage, resulting in the improvement of the COD removal efficiency from 87% at the first cycle to 95% at the fifth cycle, calculated by the Eq. (1) with COD_f = 2500 mg/L.

Hoinkis and Panten[21] have developed a new, innovative wastewater recycling process for industrial laundries. The system comprises a membrane bioreactor (MBR) with submerged plate and frame microfiltration membranes as the principal separation unit. The COD removal efficiency is found to be around 90% and the average flux is approximately 14 L/m^2 h. The STBR under study shows much better flux than the plate and frame microfiltration membranes used by the authors, but the fouling of the MF units is too rapid to make them competitive with polymer membranes.

Flux behavior of STBR after backflushing

The flux through the filter units is almost halved of the initial value after the fifth cycle of operation. Then the filters are subjected to backpressure with the expectation that the filter units will be cleaned and the initial flux will be regained. The MF filter units show backflow at a moderate backpressure and the flux behavior is followed for the sixth operational cycle. For the seventh and eighth cycle, the cleaning is performed again by mechanical rubbing and rinsing as before. The results are presented in Fig. 4. The graph is completely different from that observed before backflushing (Fig. 2). The slope of the curves is positive demonstrating the improvement of the flux with the increasing operational time. The permeate quality, however, deteriorates very rapidly. It is visualized with naked eyes that some of the filter materials are being leached out of the filter. Certainly, the filter has experienced internal damage by backflushing, which results in gradual physical destruction of the internal pore-structure of the units. Obviously, the filters do not have adequate mechanical strength to withstand backpressure and can’t be relied for long term application.

The MF unit could be used in MBR system for long term operation, if (i) the fouling of its surface could be controlled, (ii) the pore sizes could be reduced so as to prevent the microorganism-leakage and (iii) its mechanical strength is improved to withstand backpressure. Through variation of clay-sand-rice husk ratio, the important filter characteristics such desired porosity, pore-size distribution and mechanical strength could be achieved. Better result is expected, if the rice husk is burnt to ashes (which is rich in silica) and used in filter composition as substitute to raw rice husk. The ash would produce filters with finer pores than the raw rice husk does. The porosity and the flux could also be regulated varying the ash content. The outer surface is expected to be smoother for filters made from clay-sand-ash than those made from clay-sand-rice husk. During thermal treatment of the present MF composition, the rice husk is burnt leaving large holes inside the filter, making potential passage for the penetration of the microorganisms[22] and also weakening the filter unit. These disadvantages could be removed with the replacement of the rice husk with its ash.

The MF unit with its present quality can’t replace commercial polymeric membranes in MBR system. But through intensive research, the composition and the preparation technology could be modified resulting in filtration unit with improved properties. If the locally manufactured filter provides satisfactory performance in bioreactor systems, it can bring a big amount of foreign currency to the developing countries with cheap working forces, by exporting them as a suitable option for replacing expensive polymer membranes. The successful optimization of the preparation parameters of the MF units can bring also radical changes to the lives of the poor potters, who are trying hard to make their livings on the filters.

Conclusion

- The SUST-Bioreactor (STBR) system can successfully treat the laundry wastewater in short term applications maintaining the standard of effluent water quality.

- Intensive research is required to improve the pore size distribution, mechanical strength and surface smoothness of the MF units to make them competitive to polymer membranes in MBR systems.
- MF units, if improved and made suitable for application in MBR systems, would have multi-dimensional effect, such as (i) it would solve the environmental problem associated with the disposal of industrial wastewater, (ii) production of MF units is a labor- intensive process, and enormous filter units shall be demanded from the rapidly growing industrial sector in developing countries. Large number of people shall be associated with the production of these filters and this would contribute to the poverty alleviation program of the countries, and (iii) success of MF-based MBR system would inspire countries with cheap labor to build wastewater treatment plants with their own capacities and without seeking foreign aid and expensive technology.

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References

1 Yang W, Cicek N & Ilg J, *J Membr Sci*, 270 (2006) 201.
2 Lesjean B & Huisjes E H, *Desalination*, 231 (2008) 71.
3 Zheng X, Zhou Y, Chen S, Zheng H & Zhou C, *Desalination*, 250 (2010) 609.
4 Islam M A, Mozumder M S I & Uddin M T, *Indian J Chem Technol*, 15 (2008) 101.
5 Kiso Y, Jung Y, Ichinari T, Kitao T, Nishimura K & Min K, *Water Res*, 34 (2000) 4143.
6 Kiso Y, Jung Y J, Park M S, Wang W, Shimase M, Yamada T & Min K S, *Water Res*, 39 (2005) 4887.
7 Fan B & Huang X, *Environ Sci Technol*, 36 (2002) 5245.
8 Fuchs W, Resch C, Kernstock M, Mayer M, Schoeberl P & Braun R, *Water Res*, 39 (2005) 803.
9 Wang W, Jung Y J, Kiso Y, Yamada T & Min K S, *Process Biochem*, 41 (2006) 745.
10 Satyawali Y & Balakrishnan M, *Sep Purif Technol*, 63 (2008) 278.
11 Tewari P K, Singh R K, Batra V S & Balakrishnan M, *Sep Purif Technol*, 71 (2010) 200.
12 Chang I S, Gander M, Jefferson B & Judd S J, *Process Saf Environ*, 79 (2001) 183.
13 Meng Z G, Yang F L & Zhang X W, *Filtr Separt*, 42 (2005) 28.
14 Chang M C, Horng R Y, Shao H & Hu Y J, *Desalination* 191 (2006) 8.
15 Chang W K, Hu A Y J, Horng R Y & Tzou W Y, *Desalination*, 202 (2007) 122.
16 Ren X, Shon H K, Jang N, Lee Y G, Bae M, Lee J, Cho K & Kim I S, *Water Res*, 44 (2010) 751.
17 Stephenson T, Judd S, Jefferson B & Brindle K, *Membrane Bioreactors for Wastewater Treatment* (IWA Publishing, London), 2000, 4.
18 Marrot B, Barrios-Marinez A, Moulinand P & Roche N, *Environ Prog,* 23 (2004) 5.
19 Hoinkis J & Scheibner R, Waste Water Recycling Technology for Laundries, *Proceedings, Conference of Membranes in Drinking and Industrial Water Production* (Mühheim, Germany), 2002.
20 Hoinkis J & Scheibner R, *Laundry Clean News Int*, March (2002) 19.
21 Hoinkis J & Panten V, *Chem Eng Process*, 47 (2008)1159.
22 www.immt.res.in/announcement/terafil.pdf (accessed on 22 June 2012).