Biochem. Cell. Arch. Vol. 18, No. 1, pp. 331-335, 2018 | www.connectjournals.com/bca | *ISSN 0972-5075*

TREATMENT OF SYNTHETIC PHENOLIC WASTEWATER USING MBR

Shashi Kant Dubey[1]* and Athar Hussain[2]

[1]Department of Environmental Engineering, Hindustan College of Science and Technology, Farah, Mathura - 281 122, India.
[2]Department of Civil Engineering, Ch. B. P. Govt. Engg. College, Jaffarpur, New Delhi - 110 073, India.
*e-mail: shashi.dubey@gmail.com

(Accepted 20 February 2018)

ABSTRACT : Membrane bioreactor is an emerging technology used to treat diversity of wastewaters- industrial as well as municipal. MBR technology has several advantages over conventional activated sludge process as reduction of land area requirement, maintaining higher concentration of active biomass, better maintenance of shock loading, less or no use of chemicals and successful treatment of inhibitory compounds. However membrane fouling is still a challenge in use of MBR. Due to membrane fouling, operation cost as well as capital cost increases. In this work degradation of high phenol concentration has been studied using MBR. The effect of HRT and SRT on performance of membrane bio reactor has been monitored. Finally effect of SRT on membrane fouling has been studied. It has been found that membrane bioreactor can be successfully used for the treatment of high concentration of inhibitory compounds like phenol in the range of 500-3000 mg/L. A SRT of 20-25 days has been found suitable for treatment of high concentration of phenol with lower fouling potential.

Key words : Membrane bioreactor, phenol, HRT, SRT, membrane fouling.

INTRODUCTION

A membrane bioreactor (MBR) includes membrane with a biological reactor. Biomass present in biological reactor decomposes the organic matter in the influent while membrane separates the biomass in the reactor. Initially, the application of MBR was focused on tertiary treatment of secondary effluent, to improve the quality final effluent for the purpose of reuse and recycle. From last 15 years, MBRs have emerged as an effective standalone treatment technology. Membrane bioreactor has several advantages over conventional biological treatment such as better effluent quality and less requirements of chemicals and energy. MBR produces little sludge (Visvanathan *et al*, 2000). The scope of membrane bioreactor has increased rapidly with decrease in the cost of membrane (Judd, 2008; Le-Clech, 2010). Membrane bioreactor (MBR) has been used for treatment of variety of wastewater. Range of its applications covers treatment of food processing, pulp and paper, textile, tannery, landfill leachate, pharmaceutical, oily and petrochemical wastewaters. Membrane bioreactor is opted as an alternative for the treatment of high-strength, complex industrial waste water (Nagano *et al*, 1992). Membrane bioreactor is very effective for treatment of organic and inorganic pollutants (Cicek *et al*, 2003). Membrane fouling is a challenge which limits its popularity and increases the operating cost of membrane bioreactor (Le-Clech *et al*, 2006; Meng *et al*, 2009). Fouling is caused by accumulation of biomass or their products on membrane surface which depends upon various factors related with MBR operation.

Literature review

Membrane bioreactor (MBR) has been found effective in the treatment of municipal wastewater and industrial effluents with toxic contents. Researchers have used hollow fiber membrane bioreactor for degradation of phenol in the range of 1000-2000 mg l^{-1} (Yi *et al*, 2007; Marrot *et al*, 2006). Tubular ceramic membrane bioreactor has been reported as an effective wastewater treatment option (Stephenson *et al*, 2000). Ceramic ultra filtration membrane bioreactor can be used for treatment of wastewater containing phenol up to 948 mg l^{-1} producing an effluent with phenol concentration of 20 mg l^{-1} (Male and Pretorius, 2001). MBR has been reported more stable than activated sludge process for handling of shock load (Leonard *et al*, 1998). Ceramic membrane bioreactor with HRT of 4 hours and SRT of 30 has been used to treat synthetic wastewater containing phenol with concentration of 600 mg l^{-1} and removal efficiency of 72% (Ersu and Ong, 2008). Chemical oxygen demand (COD) and phenol have been successfully removed in submerged membrane bioreactor (MBR) up to 85% and 90%, respectively, at phenol concentration of 600 mg/L (Leong,

Fig. 1 : Experimental set up of Membrane Bioreactor used in present study.

2011). A two phase partitioning membrane bioreactor has been reported as very effective for treatment of industrial wastewater like phenol using solvent extraction and biodegradation (Praveen and Loh, 2015).

Fouling of membrane is main problem which prevents the widespread application of the MBR (Drews, 2010). Mechanisms of membrane fouling can be divided into (i) Gel or cake formation, (ii) pore plugging and (iii) pore narrowing. Depending on the fouling components, the fouling of membranes can be due to microbes (biofouling), organic compounds (organic fouling) or by inorganic compounds (scaling). Fouling in MBRs occurs mostly due to the accumulation of microbes and microbial products (EPS) on surface of the membrane. Extracellular Polymeric Substances (EPS) are the high-molecular weight compounds which are given by cells of biomass consisting of protein, polysaccharide, nucleic acids, lipids and other polymeric substances which promote clumping of microbes. However, decrease in EPS level decreases the floc formation in MBR. Researchers have also reported that extent of membrane fouling is independent of MLSS concentration. Sludge Retention Time (SRT) is reported to control biomass characteristics in biological treatment processes. It has been reported that Longer SRT results in less concentration of extracellular polymeric substances (EPS). MBR needs to be operated with long SRTs and low food to microorganisms (F/M) ratio for reduced production of sludge and membrane fouling. (Dubey and Hussain, 2014). Very long SRT may deactivate microorganisms which causes increases of inorganic constituents. Gao *et al* (2009) has reported that extremely low SRTs increases fouling by 10 times when lowered from a value of 10 days to 2 days.

MATERIAL AND METHODS

Set up of membrane bioreactor

External membrane bioreactor was fabricated with an aerated bioreactor, membrane unit and pump (Fig. 1). The bioreactor was made of plexiglass with a working volume of 20 L (0.4m × 0.2m × 0.3m). A commercial tubular membrane (pore size 0.5μ, area 0.05 m^2) module along with a flow booster pump (75 GPD, 90 PSI) was used with the bioreactor for membrane separation. Activated sludge was taken from municipal STP and seeded to the MBR after acclimatization to phenol (Hussain *et al*, 2015). During the operation, the bioreactor was fed with synthetic wastewater. Aeration was supplied by air pump connected to air plate diffuser to suspend the biomass and provide oxygen to the biomass.

Effect of phenol concentration

Effect of sustrate concentration on removal efficiency of the reactor is important to be investigated. Effect of phenol concentration on removal efficiency was studied by operating the reactor at various phenol concentration ranging from 500-3000 mg/L. Reactor was operated for 24 hours at each phenol concentration. Samples were collected from the reactor for determination of phenol after every 4 hours for a total duration of 24 hours.

Effect of HRT and SRT

HRT is an important parameter in MBR operation. Lower HRT values result in higher organic loading rates (OLR), which result in reduction of reactor volumes required to achieve a specified removal performance along with low substrate removal. On the other hand, higher HRTs usually results in better removal performance increasing reactor volume. In this study, different SRT was chosen in the range of 5-30 days. Reactor was operated with phenol concentration of 2000 mg/L at chosen SRT. Samples were collected from the reactor after every 4 hours up to total operation time of 24 hours and analyzed for phenol removal.

Effect of SRT on SLR

Sludge loading rate (SLR) determines the amount of food (degradable organic matter in form of COD) available to microbes (volatile suspended solids, VSS). The effect of SRT has been observed on SLR by monitoring VSS in the reactor. Reactor was operated at each SRT in the range of 5-30 days for HRT of 24 hours during which samples were collected for determination of VSS.

Effect of SRT on membrane fouling

To study the effect of SRT on membrane fouling, influent phenol concentration was kept constant at 2000 mg/L and reactor was operated at chosen SRT in the range of 5-30 days. Reactor was operated and relative flux (J/Jo) values were observed after every 20 minutes for a total duration of 300 minutes.

Methodologies

Generally methods prescribed in standard methods for examination of water and wastewater was followed (APHA, 1998).

(i) Phenol Concentration

Phenol concentration of the samples was determined by using 4-aminoantipyrine method (absorbance at 550 nm).

(ii) Microbial Concentration

Microbial concentration was measured as total suspended solids (TSS) or volatile suspended solids (VSS).

(iii) Dissolved Oxygen (D.O.)

Dissolved oxygen was measured using wrinkler methods (Standard Methods).

RESULTS AND DISCUSSION

Effect of phenol concentration on performance of membrane bioreactor

Perusal of data summerized in Fig. 2 indicates that on increasing the phenol concentration in influent the performance of MBR in terms of phenol removal decereases. Phenol removal efficiency of 100% has been observed at phenol concentration of 500 to 2000 mg/L. The efficiency reduces to 97% as the phenol concentraion increases from 2000 to 3000 mg/L. However, the phenol removal efficiency has been observed to be greater than 96% in entire study period with phenol concentrations ranging from 500-3000 mg/L at HRT of 24 hours.

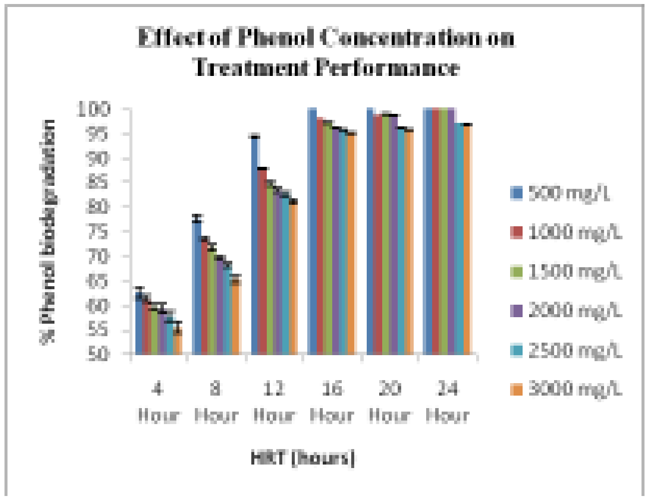

Fig. 2 : Performance of MBR at various phenol concentration (500-3000 mg/L) at different HRT (4-24 hours).

Therefore, it can be concluded that at higher phenol concentration in the influent the HRT of the MBR needs to be increased for better phenol removal.

Effect of HRT and SRT on performance of MBR

A comparision study at different SRT and HRT values has been done and is shown through Fig. 3. It can be inferred that at SRT of 20-30 days a phenol removal efficiency of 100% is achieved at phenol concentration of 2000 mg/L. However, at SRT of 30 days a phenol removal efficiency of 100% has been achieved at HRT value of 12 hours. At lower SRT of 5, 10 & 15 days phenol removal efficiency of 82%, 93% and 97% was recorded at HRT of 24 hours. Further on decreasing the SRT values, the HRT must be increased in order to increase the phenol removal efficiency. Therefore it can be inferred that the HRT has no pronounced effect on

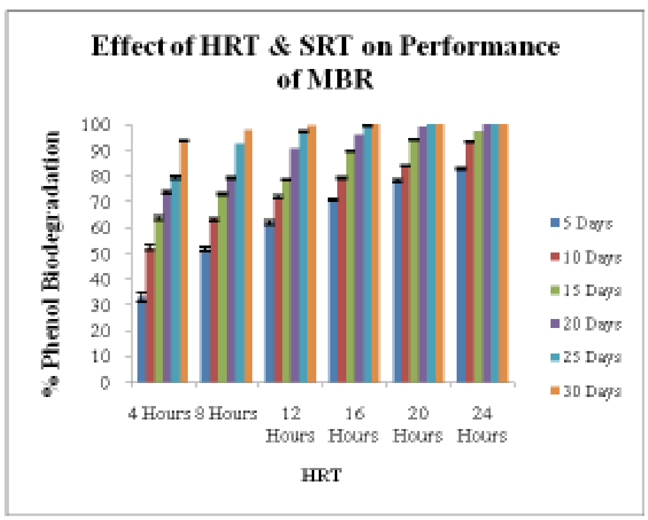

Fig. 3 : Performance of MBR for treatment of phenolic waste (2000 mg/L) at different SRT (5 Days-30 Days) and different HRT (4-24 hours).

phenol reoval efficency of MBR at higher SRT values. This phenonmenon can be attributed through a decrease in F/M ratio along with increasing SRT values.

Effect of SRT on SLR

Concentration of active biomass is important and needs to be monitored during reactor operation. It has been observed that concentration of activated sludge is related to SRT of MBR. It has also been observed that sludge loading rate (SLR) decreases from 0.75 to 0.31 on increasing SRT from 5 to 30 days indicating a low food to microbial ratio for biomass which shows better phenol removal efficiency at higher SRT values (Fig. 4).

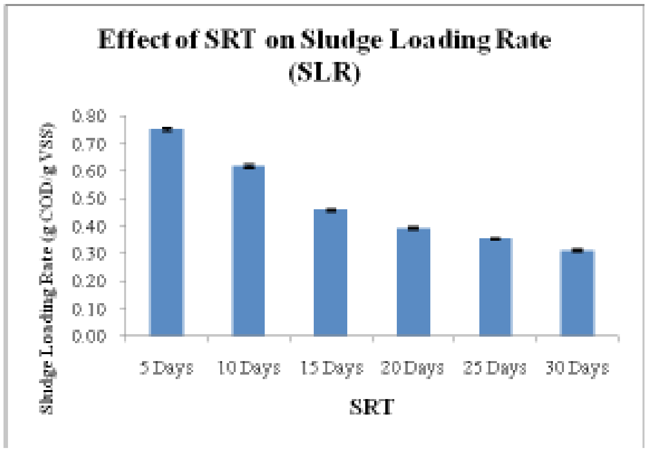

Fig. 4 : Effect of various SRT (5-30 day) on SLR in membrane bioreactor at phenol concentration of 2000 mg/L.

Effect of SRT on permeate flux

Plot of relative flux with SRT is depicted in Fig. 5 which shows decrease in relative flux with decrease of SRT. At higher SRT values F/M ratio decreases and it also reduces the formation of EPS in MBR. For lower SRT values decrease in membrane flux was observed more than at higher SRT values. For a SRT value of 30 days there was only 18% decrease in membrane flux whereas more decline was observed at lower SRT values. Relative permeate flux was recorded as 25%, 40%, 62%, 73%, 79% & 82% at increasing SRT in the range of 5-30 days.

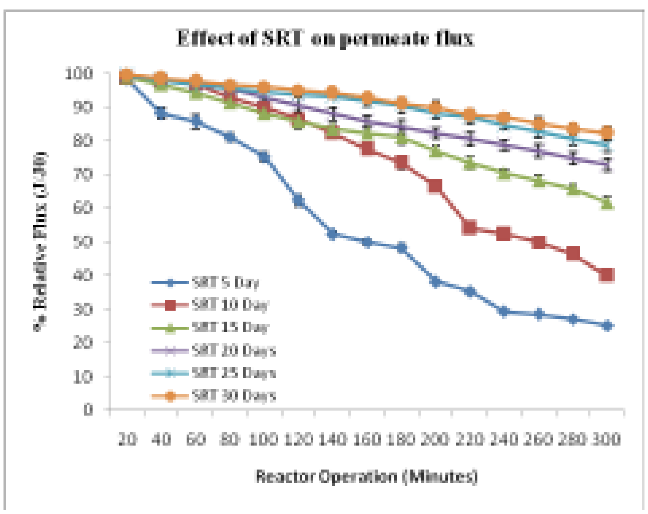

Fig. 5 : Effect of SRT on permeate flux at phenol concentration of 2000 mg/L (SRT 5-30 Day).

CONCLUSION

MBR technology is a solution for such industrial wastewater with many advantages over conventional treatment. The application of MBR covers a wide range of industrial wastewaters, which include food processing, pulp and paper, textile, tannery, landfill leachate, pharmaceutical, oily and petrochemical, and other types of industrial wastewaters. Based on the results obtained in present study MBR technology can be successfully used for the treatment of inhibitory waste like phenol. In this study it was found that phenol removal efficiency of MBR decreases from 100-97% on increasing phenol concentrations from 500 to 3000 mg/L. It has been observed that the reactor can be operated at lower HRT value of 12 hours with phenol removal efficiency of 100% at higher SRT of 30 days with phenol concentration of 2000 mg/L which shows that HRT has no pronounced effect on the performance of MBR. Sludge loading rate (SLR) decreases from 0.75 – 0.31 Kg COD/ Kg VSS.d. on increasing SRT from 5-30 days during reactor operation at phenol concentration of 2000 mg/L. Decrease in SLR indicates low food to microbial ratio and better phenol removal efficiency at high SRT.

Conflict of interest and disclosure

This research has not been financed by any institute under private or government authority.

REFERENCES

Cicek N (2003) A review of membrane bioreactors and their potential application in the treatment of agricultural wastewater. *Can. Biosyst. Eng.* **45**(6), 37–49

Drews A (2010) Membrane fouling in membrane bioreactors—Characterization, contradictions, cause and cures. *J. Membrane Sci.* **363**(1–2),1-28.

Dubey S K and Hussain A (2014) Phenol Biodegradation: A review. *Int.J. Environ. Enginering* **1**(2), 151-157.

Ersu C B and Ong S K (2008) Treatment Of Wastewater Containing Phenol Using A Tubular Ceramic Membrane Bioreactor. *Environ. Technol.* **29**, 225-234

Gao D, Fu Y, Tao Y, Wu W, An R and Li X (2009) Current Research and Development of Controlling Membrane Fouling of MBR. *African J. Biotechnol.* **8** (13), 2993-2998.

Hussain A, Dubey S K and Kumar V (2015) Kinetic study for aerobic treatment of phenolic wastewater. *Water Resources and Industry* **11**, 81-90. doi:10.1016/j.wri.2015.05.002

Judd S T (2008) The status of membrane bioreactor technology. *Trends Biotechnol.* **26**, 109–116.

Le-Clech P (2010) Membrane bioreactors and their uses in wastewater treatments. *Appl. Microbiol. Biotechnol.* **88**(6),1253-60. doi: 10.1007/s00253-010-2885-8.

Le-Clech P, Chen V and Fane A G (2006) Fouling in membrane bioreactors used in wastewater treatment. *J. Membrane Sci.* **284**, 17-53

Leonard D, Mercier-Bonin M, Lindley N D and Lafforgue C (1998) Novel Membrane Bioreactor with Gas/Liquid Two- Phase Flow for High Performance Degradation of Phenol. *Biotechnol. Progr.* **14**, 680-688

Leong M L, Lee K M, Lai S O and Ooi B S (2011) Sludge characteristics and performances of sequencing batch reactor at different influent phenol concentrations. *Desalination* **270**, 181-187

Male P C and Pretorius W A (2001) Aerobic Treatment of Inhibitory Wastewater Using a High Pressure Bioreactor with Membrane Separation. *Water Sci. Technol.* **43** (11), 51-58

Marrot B, Barrios-Martinez A, Moulin P and Roche N (2006) Biodegradation of high phenol concentration by activated sludge in an immersed membrane bioreactor. *Biochem. Engineer. J.* **30** (2), 174-183.

Meng F, Chae S R, Drews A, Kraume M, Shin H S and Yang F (2009) Recent advances in membrane bioreactors (MBRs): Membrane fouling and membrane material. *Water Res.* **43** (6), 1489-512.

Nagano A, Arikawa E and Kobayashi H (1992) The treatment of liquor waste-water containing high-strength suspended-solids by membrane bioreactor system. *Water Sci. Technol.* **26**, 887–895

Praveen P and Loh K C (2015) Phenolic wastewater treatment through extractive recovery coupled with biodegradation in a two phase partitioning membrane bioreactor. *Chemosphere* **141**, 176-182.

Stephenson T, Judd S, Jefferson B and Brindle K (2000) Membrane Bioreactors for Wastewater Treatment. *J. Membr. Sci*. **284**, 17–53.

Visvanathan C, Ben Aim R and Parameshwaran K (2000) Membrane Separation Bioreactors for Wastewater Treatment. Crit. Rev. *Environ. Sci. Technol.* **30** (1), 1-48.

Yi Li and Kai-Chee L (2007) Continuous Phenol Biodegradation at High Concentrations in an Immobilized- Cell Hollow Fiber Membrane Bioreactor. *J. Appl. Ploym. Sci*. **105**, 1732-1739.