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Treatment of Industrial Analgesic Wastewater by Submerged Membrane Bioreactor

S.Sundararaman, R.Saravanane, T.Sundararajan

Abstract- Extensive laboratory investigations were carried out using a commercially available submerged membrane (ZENON make; pore size – 0.04 µm and made of a polymeric material) for studying the treatment efficiency of an industrial pharmaceutical wastewater (obtained from a company manufacturing 'analgesic' drug). The bioaugmentation process adopted in the MBR is very effective for the treatment of the pharmaceutical effluent, as evident from the COD removal (%) obtained (ie., 82.5% @ 24 h HRT and 71.47% @ 8 h HRT, at the maximum OLR.

Index Terms: bioaugmentation, membrane bioreactor, pharmaceutical (industrial) effluent, submerged membrane

I. INTRODUCTION

Among the biological processes, MBRs have been regarded as the advanced treatment technology due to their increased effluent quality, operability with high biomass concentrations, compact reactor configurations, wide range of operating conditions such as sludge age and organic loading rates (OLRs) (Marrot et al., 2004). Manufacturing processes of pharmaceutical products lead to the release of toxic organic compounds and their metabolites into the environment. Most of the above such compounds present in the wastewater and released to the environment indiscriminately, have inherent recalcitrant behavior and are structurally complex organic compounds. More attempts were made on the process of the performance of MBR on different industrial Wastewaters (Sridang et al. (2006), Matošić et al. (2009), Zheng and Liu (2006), Yun et al. (2006); Chang et al. (2006), Qin et al. (2007); Ahn et al. (2008); Prado et al. (2009) and Benitez et al. (1995), Chen et al. (2008, 2009)) where the COD removal efficiency was more than 85%. However, research on the treatment of pharmaceutical wastewaters using MBRs as a single stage of treatment has not been investigated and reported so far. However, if the application of the above treatment is adopted, it eliminates the provision of solid thickening facilities and hence reduces land area required for treatment, apart from other advantages like low maintenance and operation cost of wastewater treatment. An attempt is made in the present study to analyse the effect of the chosen experimental parameters like organic loading rates (OLRs), hydraulic retention times (HRTs), on the treatment efficiency (COD removal %) of MBR with bioaugmentation under continuous mode of operation.

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***** Correspondence Author (s)
Dr.S.Sundararaman, Professor, Dept. of Civil Engineering, Mailam Engineering College, Mailam
Dr.R.Saravanane, Associate Professor, Department of Civil Engineering, Pondicherry Engineering College, Pondicherry
Dr. T.Sundararajan, Professor, Department of Civil Engineering, Pondicherry Engineering College, Pondicherry

II. MATERIALS

The wastewater (without treatment) was collected from a point where all the wastewater from the different stages of the pharmaceutical drug manufacturing process enters the equalization tank. Samples drawn from the above single source were continuously used for the entire experimental investigations. Wastewater was collected in 40 litres plastic cans (air tight containers) and brought to the laboratory where they are stored in a deep freezer. A sampling period of one year considered in this study is expected to cover the cyclic variations in the concentration of wastewater generated from the above industry. ZENON is a global leader in advanced membranes for water purification, wastewater treatment and water reuse to municipalities and industries worldwide (Lesjean et al., 2009) was chosen for the present study. Pore size of 0.04micrometer was chosen for the present experimental investigation.

III. METHODOLOGY

A laboratory scale bioreactor was fabricated according to the schematic diagram shown in Fig 1.0. The 'continuous mode' of operation was carried out to analyse the efficiency of the treatment process to treat the pharmaceutical wastewater, under six HRTs (24, 16, 12 ,8, 6, 4 hours) and six OLRs (for each HRT) for various diluted COD concentrations namely, 277 mg/L, 1247 mg/L, 2496 mg/L, 3744 mg/L, 4825 mg/L and 6074 mg/L at the inlet to the MBR. Based on the maximum reduction in COD (%) and VSS concentration, the best ratio 4:1 (wastewater: seed) was chosen, for using it in the continuous mode of operation. Bioaugmentation usually help conventional biodegradation processes work faster, or may provide additional, exogenous biological agents to polluted systems and improve the transformation processes (Bathe et al., 2005; Fantroussi and Agathos, 2005). COD/VSS ratio of 0.22 to 0.30 was maintained throughout the continuous operation, so as to sustain the bioaugmentation.

IV. RESULTS AND DISCUSSION

A. Effect Of Bioaugmentation

The trends in the variation of the concentration of TDS with respect to OLR and HRT is shown in Fig.2.0. The reduction in TDS gently decreases with increase HRTs and it is found to be in the range of 45 to 60%, considering the maximum OLR and the various HRTs. The trends in the variation of the concentration of TSS with respect to OLRs and HRTs are similar to that of the TDS. It is found that there is 13-42% increase in the TSS at maximum OLR, considering all HRTs.

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B.Colour

Colour of the pharmaceutical wastewater (as collected from the industry), colour of the permeate obtained after treatment by MBR with bioaugmentation, were determined by adopting the standard methods (APHA, 2005) on cobalt platinum scale. The values obtained are: 47.5 units (for raw wastewater); and 22.0 units (with bioaugmentation).This is due to the biomass added during the bioaugmentation process.

C.Volatile Suspended Solids

In the case of MBR process with bioaugmentation, the growth and sustenance of microorganism is possible due to bioaugmentation as shown in Fig. 3.0. The above fact is correlated with VSS / COD which is 0.24 (at 24 h HRT and at maximum OLR). As the above value is within the range recommended for a typical aerobic process, growth and sustenance of microorganisms is possible, thereby facilitating biodegradation of the pharmaceutical wastewater. Even though the VSS / COD at 12 h and 6 h (at maximum OLR) is in the range of 0.07 - 0.15, there seems to be growth and sustenance of the microorganisms, which is supported by the higher concentration of VSS in the MBR process with bioaugmentation, It is presumed that the higher VSS concentrations at 12 h and 6 h HRT in a way is responsible for higher COD removal (%), in the case of MBR process with bioaugmentation.

D.COD removal

Even at the highest HRT considered (ie., 24 h) COD removal (%) was 82.53% in the case of MBR process, with bioaugmentation. COD removal (%) was 71.47% at 8 h HRT, with bioaugmentation, at maximum OLR as evident from Fig.4.0. Further, comparable efficiency with that of a conventional system can be achieved if the MBR process with bioaugmentation is adopted, even at a very low HRT of 6 h. Thus, from operational perspective, there is very good flexibility and advantage, in the case of MBR with bioaugmentation. From an overall assessment, the COD removal efficiency (%) achieved for the ‘recalcitrant’ pharmaceutical wastewater (with bioaugmentation) is comparable to the reported efficiencies achieved so far and hence the treatment process proposed in this study has lot of promise for wide range of applications for wastewater treatment.

E.Sem And Edax

Fig. 5.0 shows the typical SEM picture of the outer surface of the fouled membrane. It can be seen that there is a huge deposit of foulants. The SEM obtained in this study is comparable with the SEM obtained and reported by Chang et.al., (2008), for the fouled membrane. Fig. 6.0 shows the EDAX spectra and elemental composition of the fouled membrane. It can be seen that Si, Fe, Zn (cations) were found predominantly thereby influencing the fouling of the membrane. Further, Al and Ca are present in smaller quantities, may also influence fouling of the membrane. Some quantities of chromium (about 2%) was also observed in the fouled membrane. The results of SEM and EDAX demonstrate that fouling on the membrane is mainly due to microorganisms and/or the sludge physiological properties. The fouling characteristics observed in this study are comparable to the fouling observed and reported by Chang et.al. (2008) for the treatment of a pharmaceutical wastewater (by a two stage process using SMBR).

V. CONCLUSIONS

Following are the salient conclusions drawn based on the present study:

1. The higher VSS/COD ratios in the above HRTs are in a way found to be responsible for higher COD removal (%) in the case of MBR with bioaugmentation.
2. COD removal (%) is 82.53% at 24 h and 71.47% at 8 h, at the maximum OLR considered, in the case of MBR, with bioaugmentation
3. Comparable efficiency with that of a conventional treatment system (say activated sludge process) can be achieved by the MBR with bioaugmentation, even if the reactor is operated at a very low HRT ie., at 6 h. Thus, there is a very good flexibility and advantage in the case of MBR with bioaugmentation for the treatment of pharmaceutical wastewater.
4. SEM and EDAX results demonstrate that the fouling characteristics of the membrane observed in this study are mainly due to the microorganisms and the physiological characteristics of sludge formed on the membrane.

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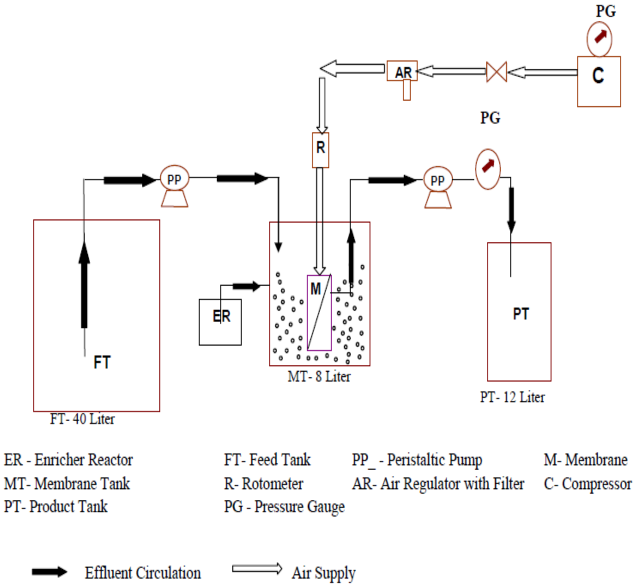

Fig. 1.0 Schematic Diagram of Laboratory Scale Membrane Bioreactor

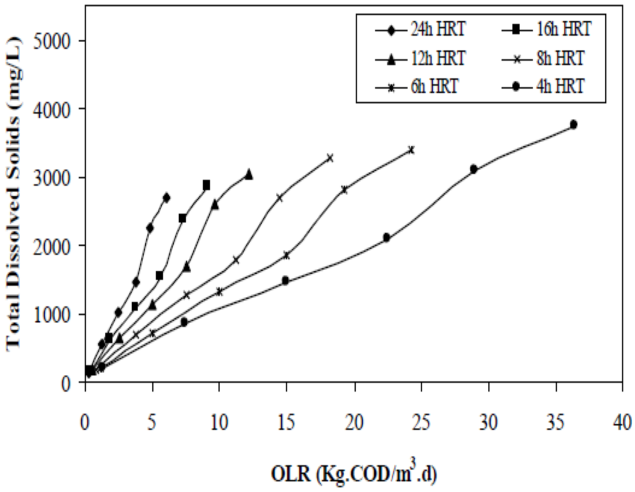

Fig. 2.0 Variation of total dissolved solids for various OLRs and HRTs (with bioaugmentation)

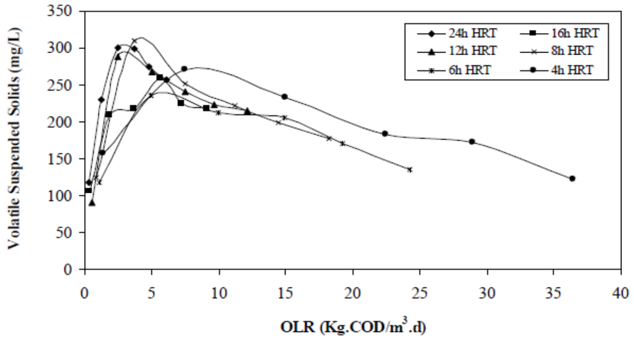

Fig.3.0 Variation of volatile suspended solids for various OLRs and HRTs (with bioaugmentation)

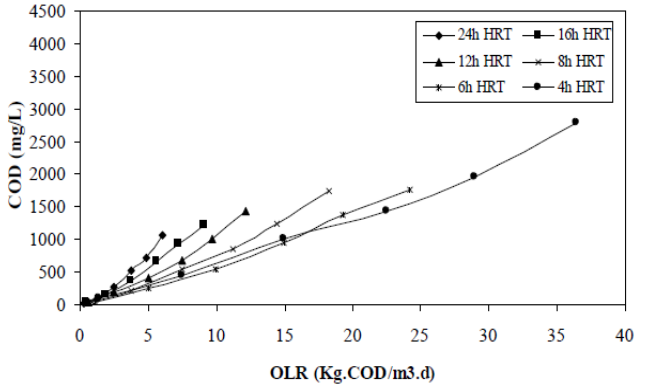

Fig.4.0 Variation of COD for various OLRs and HRTs (with bioaugmentation)

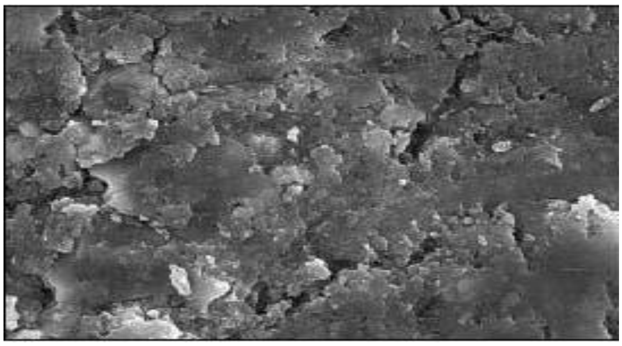

Fig.5.0 SEM of fouled membrane (outer surface)

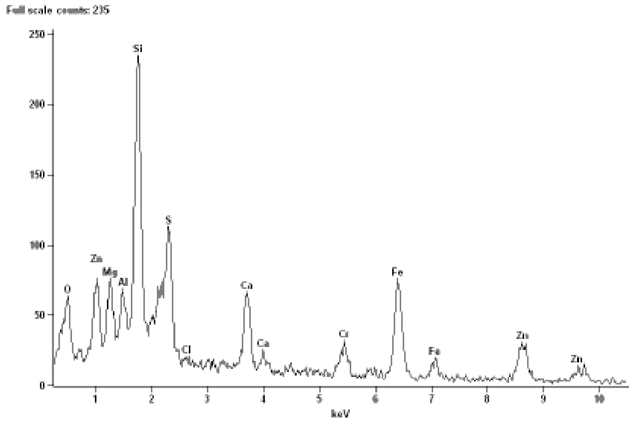

Fig. 6.0 EDAX spectra and elemental composition of the fouled membrane

Element Line	*Weight %*	*Atom %*	*Formula*
O K	42.06S	62.63	
Mg K	5.90	5.78	MgO
Al K	3.65	3.22	Al_2O_3
Si K	12.66	10.74	SiO_2
S K	6.88	5.11	SO_3
S L	---	---	
Cl K	0.41	0.27	Cl
Cl L	---	---	
Ca K	4.16	2.47	CaO
Ca L	---	---	
Cr K	2.10	0.96	Cr_2O_3
Cr L	---	---	
Fe K	11.62	4.96	Fe_2O_3
Fe L	---	---	
Zn K	10.56	3.85	ZnO
Zn L	---	---	
Total	100.00	100.00	

Fig. 6.0 EDAX spectra and elemental composition of the fouled membrane

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