ABSTRACT

Environmental awareness among the people of several well developed and developing countries have forced the various governments to continuously evolve and implement stringent effluent standards for disposal. Hence, newer technologies like the application of membrane separation (micro or ultra filtration) technique coupled with biological processes (known as membrane bioreactor – MBR) were developed, having several distinct advantages over the conventional treatment process(es). The last decade witnessed a tremendous growth in the use of MBR. However, critical review of literature has revealed that the MBR technology is very scarcely used for the treatment of recalcitrant nature of effluent (ie., pharmaceutical wastewater). Hence, in this study an industrial pharmaceutical wastewater was considered for treatment using a (submerged) membrane bioreactor.

Extensive laboratory investigations were carried out using a commercially available 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). Chemical Oxygen Demand (COD) removal (%) was obtained by operating the MBR under various organic loading rates (OLRs) ranging between 0.277 to 36.57 Kg.COD/m³.d, hydraulic retention times (HRTs) ranging from 24h to 4h without and with bioaugmentation. Mathematical models based on already published literature were used to predict the biomass concentration and slowly biodegradable substrate concentration. The results from the mathematical models were validated with experimental data. Some of the significant parameters of the treated wastewater were compared with those of the National and International standards for disposal of effluent, to assess the overall performance of the MBR treatment process.

Based on extensive experimental investigations and mathematical model studies, it is concluded that (i) 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;
(ii) the maximum efficiency (@ 24 h HRT) is nearly 70% higher than the efficiency for the case of MBR without bioaugmentation; (iii) COD removal efficiency achieved in this study (i.e., with bioaugmentation) is qualitatively comparable to the efficiencies reported so far using the MBR process for various pharmaceutical wastewaters; (iv) Bioaugmentation leads to higher frequency of ‘fouling’ than without bioaugmentation for the treatment of pharmaceutical wastewater using the MBR; (v) the predominant recalcitrant compounds present in the wastewater are: toluene, benzene/ benzaldehyde and phenol; (vi) the theoretical model used (i.e., the model proposed by Wen et al. 1999) to predict the biomass concentration and the experimental results from MBR with bioaugmentation agree very well for 24 h and 8 h HRTs (at maximum OLRs) and (vii) it is not possible to meet the disposal standards completely as laid down by National (i.e., in India) and International bodies.

Hence, MBR with bioaugmentation can be used to treat even recalcitrant wastewaters with a very high level of treatment efficiency. However, appropriate pre/post treatments have to be evolved and used in conjunction with the above technology, if the National/ International standards for disposal of effluent have to be met.

**Keywords:** pharmaceutical (industrial) effluent; membrane bioreactor (MBR); submerged membrane; bioaugmentation; mathematical modeling and MS-GC.