Hybrid Membrane Bioreactor for the Treatment of Industrial Wastewater

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Abstract: A hybrid membrane bioreactor system was developed by combining a fluidized ceramic membrane reactor with activated carbon particles for the treatment of industrial wastewater. A ceramic membrane consisting of Al_2O_3 with 0.1 µm pore size was submerged into a fluidized reactor. Granular activated carbon (GAC) particles were fluidized by recirculating bulk solution through the reactor. GAC fluidization in the system increased the critical flux by 46%, while total organic carbon (TOC) removal was 90% higher as compared with the control system having no GAC. Furthermore, GAC assisted system reduces the fouling at lower upflow velocities that ultimately reduced the fluidization cost. Total suspended solids (TSS) concentration was near zero in membrane permeate. During 8 hr operation, no increase in suction pressure was observed under GAC fluidization 50% (v/v) at 25 an d50 L/m^2.h of set-point flux.

Keywords: Wastewater treatment; Membrane bioreactor; Granular activated carbon; Industrial wastewater

Introduction

Membrane fouling caused by deposition of foulant materials on membrane surface/or with pore matrices is a key challenge in membrane bioreactors (MBRs) as it reduces membrane lifetime and increases capital and operational costs. Recently introducing the granular activated carbon (GAC) as fluidized media into submerged MBRs can mitigate membrane fouling at relatively low energy consumption (Kim et al., 2011; Aslam et al., 2017). GAC as fluidized media serves multiple functions, including support media for microorganisms, an abrasive material that helps to clean membrane surface mechanically and medium for adsorption of organic materials present in wastewater to be treated (Aslam et al., 2017). However, long-term exposure of polymeric membranes to GAC sparging causes membrane damage (Aslam et al., 2014). Recently, there is a growing interest in ceramic membranes for MBR systems due to its technical advantages. Nevertheless, practical implementation of ceramic membranes has been limited due to the high cost of raw materials for most commercialized ceramic membranes such as alumina, titania and silicon carbide. However, elucidating cost-effective ceramic membranes using natural-mineral based materials (kaolin, dolomite, Moroccan clay, and pyrophyllite) alternative to conventional materials yet require further research. In addition, the sintering temperature of these materials (i.e.,1300^{o}C) is substantially lower than that of alumina (i.e., 1600 ^{o}C). Therefore, the pyrophyllite-based ceramic membrane could be an effective alternative for cost reduction. However, so far, the natural mineral-based ceramic membrane has not been applied to fluidized bed membrane systems. For this reason, this study evaluated the feasibility of pyrophyllite ($Al_2Si_4O_{10}(OH)_2$), one of the abundant natural-minerals, as a based ceramic membrane in membrane bioreactor for treating textile wastewater using GAC as fluidized media.

Materials and Methods

A bench-scale fluidized bed membrane reactor (HFMR) equipped with a submerged pyrophyllite-based ceramic membrane with a pore size of 0.1 µm was operated at a high permeate flux of 25 and 50 L/m^2/h. Membrane fouling and removal efficiency of pyrophyllite ceramic membrane were compared with commercially available alumina ceramic membrane under similar conditions. The total volume of the reactor and effective membrane surface area were 4.4 L and 0.035 m^2 respectively. The feed to the HFMR consisted of synthetic dye wastewater. The 10x20 mesh GAC particles were fluidized in the HFMR by recirculating bulk solution through the reactor. A diffuser was installed at the bottom of the reactor to allow entrance of recirculating bulk suspension to fluidize GAC particles to rise and cover the whole surface of the ceramic membranes. The organic removal efficiency with time was monitored, and suction pressure required to maintain the constant flux was used as fouling indicator.

Results and discussion

The feasibility of natural mineral-based pyrophyllite ceramic membrane was evaluated as an alternative to conventional membrane materials in HFMR for textile wastewater. Results showed that fluidized GAC with pyrophyllite ceramic membrane increased critical flux by approximately 46% than that achieved in the absence of GAC. HFMR can be operated with GAC even with the reduced upflow velocities with better fouling reduction. Overall total organic carbon (TOC) removal was observed higher than 90% with GAC particles as fluidized media. The electrical energy required for complete fluidization were 0.019 kWh/m^3 with GAC fluidization, which was much less than that of combined with gas sparging to control membrane fouling. Intermittent GAC fluidization did not affect the removal efficiency and fouling control, and 5 min/5 min off could be an optimum strategy for intermittent fluidization to save additional energy demands.

Conclusions

The results suggest that pyrophyllite-based ceramic membrane could be feasible and promising to treat textile wastewater in HFMR. The filtration performance and removal efficiency were comparable between pyrophyllite and alumina ceramic membrane. Future research related to process optimization and membrane improvement should be focused on its practical applications and up-scale purposes.

References

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