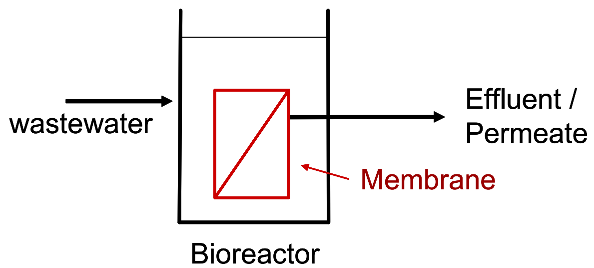
Membrane Bioreactor for Wastewater Treatment

Recent technical innovation and significant membrane cost reduction have pushed membrane bioreactors (MBRs) to become an established process option to treat wastewaters. The combination of membrane separation with a suspended growth bioreactor is now widely used for municipal and industrial waste treatment (Judd, 2006). When used with domestic wastewater, MBR processes could produce effluent of high quality enough to be discharged to coastal, surface or brackish waterways or to be reclaimed for urban irrigation. Other advantages of MBRs over conventional processes include small footprint, easy retrofit and upgrade of old wastewater treatment plants into MBRs. However, membrane fouling remains a major drawback, limiting the wider application of this process.



Simple schematic of a submerged MBR

Fouling: Major Drawback

In recent reviews covering membrane applications to bioreactors, it has been shown that, as with other membrane separation processes, membrane fouling is the most serious problem affecting system performance (Le-Clech *et al.*, 2006, Kim *et al.*, 2001). Fouling leads to a significant increase in hydraulic resistance, manifested as permeate flux decline or transmembrane pressure (TMP) increase when the process is operated under constant-TMP or constant-flux conditions respectively. Frequent membrane cleaning and replacement is therefore required, increasing significantly the operating costs. Membrane fouling results from interaction between the membrane material and the components of the activated sludge liquor, which include biological flocs formed by a large range of living microorganisms along with soluble and colloidal compounds. The suspended biomass has no fixed composition and varies both with feed water composition and MBR operating conditions employed. Thus though many investigations of membrane fouling have been published, the diverse range of operating conditions and feedwater matrices employed, and the limited information reported in most studies on the suspended biomass composition, has made it difficult to establish any generic behaviour pertaining to membrane fouling in MBRs specifically.

Submerged MBR

With the membrane directed immersed into the bioreactor, submerged MBR systems are usually preferred to sidestream configuration (with the membrane situated into a pressurised external loop), especially for domestic wastewater treatment. The submerged configuration relies on coarse bubble aeration to produce in-tank recirculation and limit fouling. The energy demand of the submerged system can be up to 2 orders of magnitude lower than of the sidestream systems (Gander *et al.*, 2000) and submerged systems operate at a lower flux, demanding more membrane area. In submerged configurations, aeration is considered as one of the major parameter on process performances both hydraulic and biological. Aeration maintains solids in suspension, scours the membrane surface and provides oxygen to the biomass, leading to a better biodegradability and synthesis of the cell (Dufresne *et al.*, 1997). The air-induced cross flow can efficiently remove or at least reduce the fouling layer on the membrane surface. A recent review reports the latest findings on applications of aeration in submerged membrane configuration and described the enhancement of performances offered by gas bubbling (Cui *et al.*, 2003). As an optimal air flow-rate has been identified behind which further increases in aeration have no effect on fouling removal, the choice of aeration rate is a key parameter in MBR design.

Fouling control

Many other anti-fouling strategies have been proposed for MBR applications. They comprise, for example, intermittent permeation, where the filtration is stopped at regular time interval for a couple of minutes before being resumed. Particles deposited on the membrane surface tend to diffuse back to the reactor; this phenomena being increased by the continuous aeration applied during this resting period. Membrane backwashing is another common anti-fouling technique, where permeate water is pumped back to the membrane, and flow through the pores to the feed channel, dislodging internal and external foulants. A small amount of cleaning agents (like hypochloride) could be added to the permeate water to improve the removal efficiency. Because of the relative long time necessary to build up liquid back-pressure, the efficiency of the liquid backwash is somehow limited as the liquid prefers to go through open (not fouled) pores. This could be improved by using pressurized air in the permeate side of the membrane to build up and release a significant pressure within a very short period of time. Membrane modules therefore need to be in a pressurised vessel coupled to a vent system. Air usually does not go through the membrane. If it was, the air would dry the membrane and a rewet step would be necessary, by pressurizing the feed side of the membrane.

MBR Suppliers

The design of the reactor (including membrane, baffle and aerator locations) and the mode of operation of the membrane also appear as key parameters in the optimisation of the system. Several immersed MBR designs are currently proposed by the leading membrane suppliers such as Zenon (Canada), X-Flow (The Netherlands), USFilter (USA), Mitsubishi and Kubota (Japan). In each case, the process proposed is very specific. Not only the membrane material and configuration used are different, but the operating conditions, cleaning protocols and reactor designs also change from a company to another. For example, the flat sheet membrane provided by Kubota does not allow backwash operation, while hollow fibre membrane type from Zenon and Memcor (USFilter) have been especially designed to hydraulically backwash the membrane on a given frequency (around every 10 min).

References

Z.F. Cui, S. Chang, A.G. Fane, The use of gas bubbling to enhance membrane process, J. Memb. Sci. 2211 (2003) 1-35.

R. Dufresne, R.E. Lebrun, H.C. Lavallee, Comparative study on fluxes and performances during papermill wastewater treatment with membrane bioreactor, Canadian J. Chem. Eng. 75 (1997) 95-103.

M. Gander, B. Jefferson, S. Judd, Aerobic MBRs for domestic wastewater treatment: a review with cost considerations. Sep. Purif. Techn. 18 (2001) 119-130.

S. Judd, The MBR book (2006) Principles and applications of membrane bioreactors in water and wastewater treatment, Elsevier, Oxford.

J.S. Kim, C.H. Lee, I.S. Chang, Effect of pump shear on the performance of a crossflow membrane bioreactor, Wat. Res. 35 (2001) 2137-2144.

P. Le-Clech, V. Chen, A.G. Fane, Fouling in membrane bioreactors used for wastewater treatment – A review. J. Memb. Sci. 284 (2006) 17-53.