Lebrero R, Muñoz R, Kumar A, Van Lagenhove H. Membrane Bioreactors for Waste gas Treatment. In: Air Pollution Prevention and Control - Bioreactors and Bioenergy. Edited by: C. Kennes & M.C Veiga. Wiley-Blackwell, 2013, pp.155-184

Membrane Bioreactors for Waste Gas Treatment

Raquel Lebrero, Raúl Muñoz, Amit Kumar, Herman Van Langenhove

1. Introduction

The increasing public concern about atmospheric pollution has resulted in the past years in more stringent environmental regulations to limit the emission of gaseous pollutants such as SO_x, NO_x, volatile organic compounds (VOCs), volatile sulphur compounds (VSCs), odours, etc. (De Nevers 2003, Lebrero et al. 2011). In this context, VOCs and VSCs represent a major environmental problem worldwide due to their toxicity, mutagenicity or carcinogenicity, their role in tropospheric ozone formation and to odour nuisance provoked in the nearby population (Sucker et al. 2008, Revah and Morgan-Sagastume, 2005). Therefore, the minimization and control of these gaseous emissions rank nowadays among the top priorities of most chemical, petrochemical or pulp and paper industries, animal farming and waste treatment facilities, in order to move towards more sustainable production processes and because of the increasing concerns about their public image.

Among the battery of *end-of-pipe* treatment technologies available nowadays, biological-based technologies (biofiltration, activated sludge diffusion, biotrickling filtration, bioscrubbing, etc.) exhibit significantly lower environmental impacts (in terms of energy and chemicals consumption and CO_2 footprint) than their physical-chemical counterparts (activated carbon adsorption, chemical scrubbing, incineration, ozonation, etc.) (Mudliar et al. 2010, Estrada et al. 2011). In addition, despite exhibiting higher initial investment costs, the lower operational costs of the biotechnologies during waste gas treatment render them as the most economic option in a 20-30 years horizon when treating large waste gas flows containing low concentrations of pollutants (Estrada et al. 2011). Only when process robustness is considered, physical-chemical technologies offer a better treatment performance, although research is rapidly reducing this gap (Estrada et al. 2012). Among conventional biotechnologies, biofiltration and biotrickling filtration are by far the most commonly used for VOC/VSC/odour abatement likely due to their ease of operation and accumulated design and operation experience (Kraakman et al. 2011, Iranpour et al. 2005). However, both biotechnologies face important limitations when treating poorly water soluble volatile compounds and the cost-effective control of biomass overgrowth in both systems still remains unsolved (Kraakman et al. 2011). In the particular case of biofiltration, filter media acidification, drying and compaction (with the subsequent formation of preferential pathways) or the accumulation of toxic metabolites significantly reduce the lifespan and long-term performance of this technology (Kennes and Thalasso 1998). On the other hand, while activated sludge diffusion systems are economically viable exclusively during odour treatment in wastewater treatment plants provided with aeration via air diffusion, the use of bioscrubbers is limited by their high investment costs and limited performance when treating poorly water soluble compounds (Burgess et al. 2001, Delhoménie and Heitz 2005).

Advanced membrane bioreactors represent a promising alternative to conventional biotechnologies to overcome most of the above mentioned limitations (Kumar et al. 2008). Membrane bioreactors for waste gas treatment (MBRWG) can combine the selective extraction of the target gaseous pollutants and O_2 from the contaminated air emission (circulating through one side of the membrane) with their biodegradation by a microbial community attached on the other side of the membrane (or in suspension) in contact with a discrete aqueous phase containing the nutrients required for microbial growth (Semmens 2008). Hence, the membrane acts as an interphase between the gas and the microbial community, and the gaseous pollutants either diffuse through the membrane pores (porous or microporous membranes) or permeate via solution-diffusion mechanisms (dense membranes or composite membranes). The presence of a biofilm or a culture suspension on the other side of the membrane increases the local concentration gradients (due to the rapid consumption of the gaseous pollutants and O_2) and therefore the overall mass transfer rates (Semmens 2008). In addition, this technology is available in several bioreactor configurations (flat-plate, hollow fiber, tubular) and provide gas-liquid interfacial areas as high as 20000 m^2 m^{-3} (De Bo et al. 2003a). The presence of a discrete water phase in advanced membrane bioreactors for waste gas treatment overcomes the typical operational limitations of biofiltration such as media acidification, accumulation of inhibitory byproducts or biofilm drying. The high selectivity of some hydrophobic membrane materials such as polydimethylsiloxane or polyolefin can enhance the mass transfer of poorly water soluble compounds as a result of the increased concentration gradients mediated by these materials (Kumar et al. 2008, Muñoz et al. 2007). In addition, the gas and liquid flow rates can be varied independently without problems of flooding or foaming (Ergas 2001a). This technology has been successfully tested for the treatment of BTEX, dimethyl suphide (DMS), trichloroethylene (TCEt), NO_x, etc. (Kumar et al. 2008).

This chapter reviews the basic principles, merits and limitations of advanced membrane bioreactors for overcoming some of the key operational limitations of conventional biological systems during waste gas treatment. Recommendations are made for design and operation of this technology while the areas needing further research and the most recent applications are identified.