ABSTRACT

Even though Membrane BioReactors (MBRs) are nowadays widely employed for municipal and industrial wastewater treatment, there is still a lack of understanding in several aspects. This is due to the complexity of the process, and its major drawback consists in a poor management of the fouling issue in many wastewater treatment plants. This is why researchers have put a great effort to understand MBR fouling in detail and to develop high-flux or low-cost membranes. In the last years, a number of studies have been published concerning fouling in MBRs, and this work aims to develop innovative ways to control fouling in Membrane BioReactors. It has to be noted that fouling phenomena are still hard to predict, given their dependence on a large number of elements.

Currently, full scale MBRs rely on physical and chemical cleaning protocols to reduce fouling that develops onto the membrane. Fouling causes TransMembrane Pressure (TMP) to rise up to levels that force plant managers to stop regular filtration and backwash/soak the unit using chemicals such as NaOCl, $C_6H_8O_7$ or $H_2C_2O_4$. Needless to say, this option raises operating costs and does not prevent fouling to develop further, once regular filtration is in place again. On the other hand, without such protocols membranes would fail soon because of sludging and subsequent drying phenomena that occur once solids accumulated at the bulk-membrane interface compress and prevent water to reach the membrane.

Many research studies aimed at enhancing cleaning protocols in MBRs, and many others focused on understanding this phenomenon. Despite all the effort put in this matter, the MBR industry still deals with the fouling issue in the same way. This work therefore aims to propose new ways to deal with the fouling issues, that might a) reduce the phenomenon in terms of its development on the membrane surface; b) reduce the compressibility of the fouling layer that develops onto the membrane; c) help tracking the development of the fouling layer and add information about the propensity of a sample to foul the membrane.

Research has been carried out at the University of Salerno, Italy (Sanitary Environmental Engineering Division – Civil Engineering Department) for the first two years, and at the University of Washington, US (Civil and Environmental Engineering Department) for the third year. Throughout the doctoral program, three different experimental setups have been developed:

- a first one composed of a membrane unit and a TMP transducer, to filter a solution that resembled a biological effluent from a urban wastewater treatment plant;
- a second one, a complete lab scale MBR that treats synthetic wastewater and can be remotely controlled through a sophisticated system of recording/storing data;
- a third one, still a complete lab scale reactor, henceforth named Bio-Entrapped Membrane Reactor (BEMR), in which a different biological degradation system has been introduced.

Results of the research activity pursued throughout the doctoral program can be summed up as follows:

- Results from the first phase show that significant reductions in TMP levels (up to 40% after 3 hours) can be achieved, the greatest enhancement being accomplished with larger nanoparticles, which provided wider channels for the bulk to filtrate.
- Results from the second phase show that the BEMR showed almost complete biodegradation of organic matter – feeding the reactor with a synthetic wastewater of 300 mg/L as COD. Residual COD in the biological effluent was due to detached biomass, as sCOD tests showed.
- TMP trends at 20, 30 and 40 LMH showed fair reduction of pressure values if compared to a conventional MBR. This result points out the benefits in terms of membrane life and operating costs of implementing BEMRs instead of conventional MBRs.
- Both MBR and BEMR produced primarily colloidal TEP, which likely caused membrane pores clogging.
- Results from the third phase, as the first attempt to monitor the TEP concentration in a BEMR, highlights the potential of this parameter as a fouling indicator for MBR/BEMR systems. TEP

showed the typical behavior of microbial by-products after experiencing a process disturbance, after which the concentration of TEP increased, whereas SMP concentrations in the units stayed stable.

- The BEMR produced less TEP than conventional MBRs due to slow-growing microorganisms with long SRT in the new bioreactor.

BEMR represents therefore an innovative way of dealing with the fouling issue. The implementation of entrapped biomass reduces the amount of biological degradation byproducts that eventually reach the membrane surface, therefore limiting fouling. Although the system has to be tested at full scale level, it looks promising for wastewater treatment and further research can develop further the idea.