THE CHALLENGE

Integrated Membrane Systems (IMS) combining microfiltration (MF) or ultrafiltration (UF) and nanofiltration (NF) or reverse osmosis (RO) membranes are increasingly being utilized for the advanced treatment of municipal wastewater for irrigation, environmental purposes (protection or restoration), industrial use or potable reuse.

The operation of membrane processes for wastewater reclamation typically have a number of associated challenges including the increased energy cost when compared to non-membrane processes, membrane fouling (reduced permeability and membrane lifetime), the safe disposal of the concentrated brine stream into the natural environment and the difficulty in monitoring process integrity in real-time.

THE PROJECT

This work addresses a number of these challenges by utilizing experience gained in operating membrane reclamation facilities and historical data to develop a decision-making framework to monitor and control an integrated membrane system in real-time, leveraging knowledge gained of advanced treatment processes and water quality sensor technology to feed information into an online decision support system.

Integrated membrane systems for wastewater reclamation can be operated with a high level of confidence with regards to membrane integrity, process reliability and performance optimization by utilizing real time detection of water quality fluctuations and treatment process condition deviations which can be processed to make real-time process decisions.
METHODOLOGY

• The fate of pharmaceutically active compounds (PhAC) and their transformation products in IMS was studied through the MBR-NF/RO process to understand the extent of their removal and how this is affected by changing process conditions (biological process, membrane fouling, system flux and recovery).

• Treatment and minimization of the RO concentrate stream is being studied by using advanced oxidation processes in the reduction of organic content of the concentrate, the mineralization of specific micropollutants and the increase of biodegradability of recalcitrant organics. Work was also carried out to understand how biological nutrient removal and filtration performance of an MBR is affected when introducing the reject stream back into the influent of the MBR to increase the overall recovery.

• Online monitoring and control of NF membrane fouling is another component of the work which builds on other peoples work as regards RO process modeling and system optimization but is tailored to integrated membrane processes for wastewater reclamation. The novelty in the work is in utilizing available online process and water quality data combined with historical water quality data to obtain fouling risk indicators that are then combined with the RO process model in the optimization-based control system to minimize the total water cost.

RESULTS

• The fate of select PhACs and their transformation products – Results showed near complete removal by the MBR for analgesics; Ibuprofen and Acetaminophen together with their main human metabolites but poor removal for compounds with limited sorption to biomass such as the psychiatric drugs Venlafaxine and Carbamazepine. Near complete removal (>99%) by the RO membrane was shown over various process conditions, making it hard to notice increased removal efficiencies as the membrane became fouled. At similar average permeate fluxes, the NF membrane showed high removal efficiencies (>90%) for all of the PhACs and their metabolites.

• Treatment of the RO concentrate stream – Preliminary results from experiments show that the objectives of reducing organic matter and increasing the biodegradability of the remaining portion is possible by 20-30% although the required hydrogen peroxide dose and fluence applied is very dependent on the quality of the concentrate which is a function of the quality of the influent as well as MBR and RO/NF process parameters.

• Online monitoring and control of NF membrane fouling – A decision tree was developed to monitor NF membrane fouling by using normalized salt rejection and permeate flux while calculating a number of fouling risk indices to help the operator decide whether the NF process parameters and pretreatment conditions are optimized in terms of energy, chemical use and fouling risk or if changes should be made.

APPLICABILITY IMPLICATIONS / BENEFITS

• Online decision support systems for integrated membrane systems for wastewater reuse will be an essential part in aiding plant operators optimize energy use and thus reduce the total cost of reclaimed water while ensuring the reliability of the membrane barriers within the process.

• Decision support systems for integrated membrane systems may also be a useful tool for reclaimed water providers to instil confidence in the continuous reliability and robustness of the multi-barrier process of which the membranes are essential components both to public health regulators as well as the public in general, particularly where potable reuse schemes are planned.

GRAPHICS

Figure 1 - The removal of select PhAC compounds and their transformation products by RO membranes (black bar) and NF membranes (white bar).