Factsheet
Reverse osmosis

Reverse osmosis in wastewater treatment for water reuse

Reverse osmosis (RO) is a separation process based on the use of semipermeable polymer membranes. It is suitable to remove dissolved substances such as salt almost entirely from the treated wastewater (Melin & Rautebach 2007). The procedure therefore is already established for decades as the treatment of process water for industrial use.

Next to a partial or complete desalination, the RO is also capable of eliminating critical trace substances (pharmaceutical, industry and household chemicals) from the water. An obstacle in the process however is the so called 'fouling'. In the context of water reuse mainly bio fouling is the problem. This is the formation of biologically active coating layers on the membranes, which can lead to pressure loss and a lower water permeability (higher energy demand) of the membrane. This in return leads to a higher cleaning frequency and a higher demand for cleaning chemicals, which increase the costs.

Objective of the studies within MULTI-ReUse is to identify the operating parameters, membrane properties and the pre-treatment set-up that minimize the formation of fouling, which in return guarantees a safe operation of the reverse osmosis procedure.

Technology

The core of a RO membrane is the polyamide layer. It is produced via interfacial polymerisation from the monomers mPDA (m-phenylendiamine) and TMC (Trimesoylchloride, see figure 1). The polyamide layer is responsible for the retention of the substances from the water, therefore it is called the 'active separation layer'. Typical for the active separation layer is the low layer thickness of about 200 nm. It also is possible to adapt the active separation layer to the requirements of different applications. Thus, RO membranes with a very high water permeability and a reliable retention capability can be produced, as it is the case with the Lewabrane® ULP (Ultra low pressure) membrane.

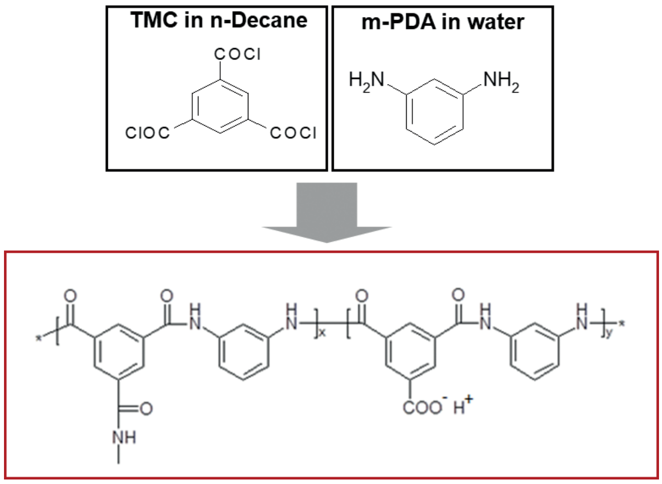

Figure 1: Polymerisation process

These are particularly of interest for the application in water reuse, because the inlet water usually doesn't contain high salt concentrations and therefore only a low osmotic pressure needs to be overcome. Together with the high water permeability, the RO can be operated on low pressure level, which in return saves energy.

However, there is the need to investigate if membranes with a lower surface charge and a lower permeability (Lewabrane® FR membrane) are less prone to fouling through adsorptive processes. The question is if these advantages compensate the in the beginning higher energy costs in the long term.

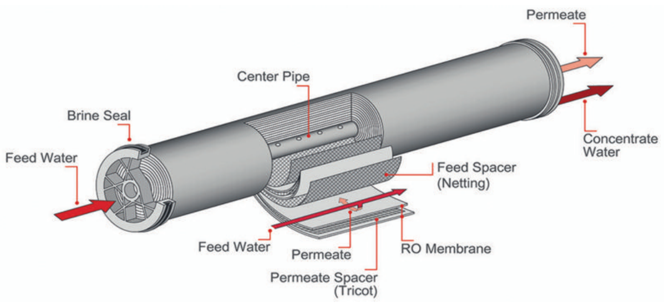

Figure 2: Structure of a spiral wound module

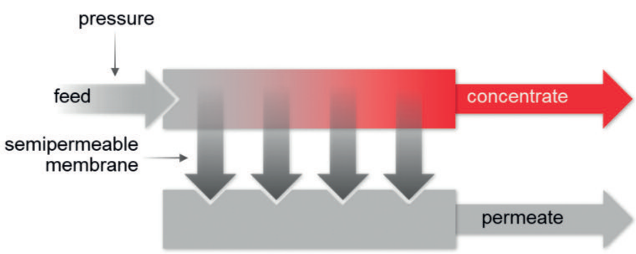

Figure 3: Tangential inflow into the RO membrane

A main reason for the fouling susceptibility of the RO is based on the module configuration that is used for large-scale applications. The membrane envelopes are spiral wound around a permeate pipe (spiral wound modules, figure 2). The single membrane envelopes are built from two RO membranes that are agglutinated at three sides. Between the membrane envelopes so called feedspacers (grid-like spacers) guarantee a feed channel for the inlet water. Spiral wound modules offer the advantage of a high packing density and feedspacers guarantee good flow conditions within the module, in which then membranes are tangential overflowed (figure 3), which guarantees a good mass transfer. On the other hand the small feed channel is prone to fouling deposits. These can be removed by cleaning processes, which should take place at least every six months. A few cleaning procedures for different kind of sediments are listed in table 1.

Table 1: Cleaning approaches for different sediments

Cleaning method	Cleaning function
pH 12 (e. g. NaOH) with or without tenside	Removal of biofouling
Citric acid (2%) at pH 4	Removal of iron and salts (e. g. $CaCO_3$, $CaSO_4$)
HCl (0.2 %)	Removal of iron, manganese and salts

Fouling control

An important aspect in regards to performance and fouling avoidance of RO depends on the pre-treatment of the inlet water. The most promising procedure is a combination of ultrafiltration (UF) and RO (figure 4). Within MULTI-Reuse those two processes are coordinated and optimized by adding flocculants and activated carbon. There also is a regular plant disinfection.

Furthermore, an innovative feedspacer design (alternating strand design – ASD) is being investigated in MULTI-ReUse. The ASD feedspacer has different filament diameters compared to the standard spacer; thick filaments alternate with thin ones, which leads to less areas with low overflow (figure 5). These are the areas where deposits form the most.

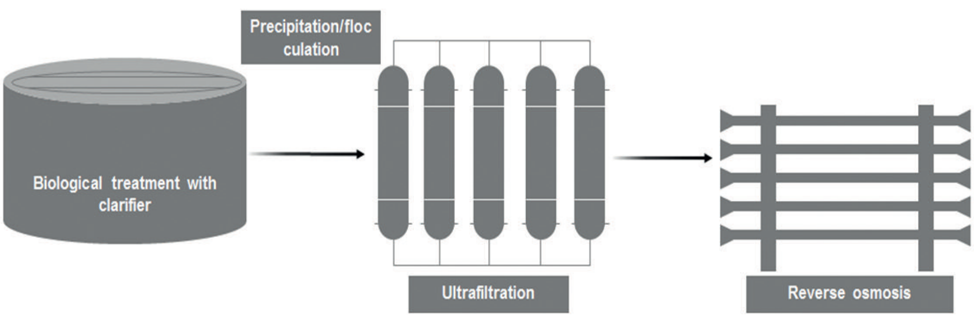

Figure 4: Wastewater treatment in the MULTI-ReUse pilot plant

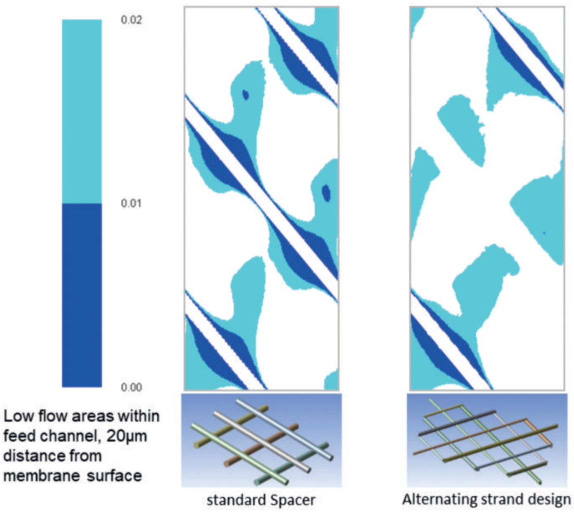

Figure 5: Flow simulation for different types of spacers

Figure 6: Comparison: Membrane surface of the ASD element on the left, standard spacer on the right.

On a laboratory scale, studies at the TU Delft showed that the ASD spacer leads to a slower increase in pressure because of the accumulation of bio mass (Siddiqui et al.). Within MULTI-ReUse these results could be confirmed under real conditions (figure 6 and figure 7). The retention of salt of the RO membranes is significantly over 99 %, independent from the spacer type used.

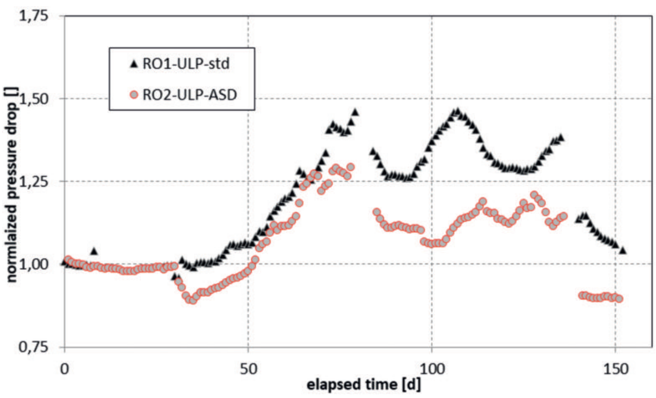

Figure 7: Normalized pressure loss, comparison between ASD and standard spacer

To reduce membrane fouling during RO and to reliably operate the processes economically and ecologically, an overall concept is necessary. Only a harmonic interaction of all listed measures (choice of the right type of membrane, adapted pre-treatment, defined operating parameters) is the path to success. For this purpose, MULTI-ReUse delivers very important insights and results.

Literature

Melin, T., Rautenbach, R. (2007): Membranverfahren: Grundlagen der Modul- und Anlagenauslegung. Springer-Verlag

Siddiqui, A., Lehmann, S., Bucs, Sz. S., Fresquet, M., Fel, L., Prest, E. I. E. C., Ogier, J. et al. (2017): Predicting the impact of feed spacer modification on biofouling by hydraulic characterization and biofouling studies in membrane fouling simulators. Water research 110, 281–287

Authors

Dr. Jens Lipnizki, Lanxess Deutschland GmbH
jens.lipnizki@lanxess.com

Uli Dölchow, IAB Ionenaustausch GmbH Bitterfeld
uli.doelchow@lanxess.com

Short description of the MULTI-ReUse project

Treated wastewater is an important part of the water cycle. It usually is fed into rivers, something that is acceptable from an environmental point of view but for the use in agriculture or industry the water often is unsuitable. MULTI-ReUse closes this gap by developing and implementing of new procedures for the reuse of service water. The aim of MULTI-ReUse therefore is the development, demonstration and evaluation of a modular water treatment system, in order to offer service water in different qualities and quantities for the different purposes and to competitive prices.

Imprint

This factsheet was produced within the research project MULTI-ReUse, funded by the Federal Ministry of Education and Research (BMBF) under the number 02WAV1403 and within the WavE support measure.

IWW Rheinisch-Westfälisches Institut für
Wasserforschung gemeinnützige GmbH
Moritzstr. 26
45476 Mülheim an der Ruhr
Germany

Website: https://water-multi-reuse.org/
E-Mail: info@iww-online.de

Legally responsible:
Dr.-Ing. Wolf Merkel (Chief Technical Officer)

November 2018

SPONSORED BY THE
Federal Ministry of Education and Research