INHIBITORS FOR CaCO$_3$-SCALING IN REVERSE OSMOSIS-PLANTS – INFLUENCE OF SUSPENDED MATTER ON MEMBRANE CLOGGING

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Abstract

Calcium carbonate (CaCO$_3$) is the most common source of mineral scaling in reverse osmosis plants, and it is a standard approach to add so-called anti-scalants to avoid membrane blocking. Although anti-scalants are used for many years, it remains a challenge to determine the most effective anti-scalant and its necessary dosage for a given water.

The reason why, is the complex process of the crystallization phenomenon, which can be described as a sequence of three processes: supersaturation, nucleation and growth of crystals. These processes can take place both in the bulk solution as well as on the membrane surface. The nucleation and the crystal growth steps are controlled in particular by the degree of supersaturation.

To measure the effectiveness of anti-scalants in a reliable way a membrane-based method has to be applied, because the interaction with the membrane and the real operating conditions of an RO plant are neglected in standard jar tests. Furthermore, the supersaturation in the standard tests is by far higher than in a real plant, so that nucleation preferably takes place compared to crystal growth.

In order to achieve results that match with the real operating conditions, a new membrane-based method (Fig 1 and Fig 2) combined with a laser diffraction particle-size analyzer (Beckman Coulter LS 13320) was applied, investigating the performance of three phosphorus-free anti-scalants of different chemical structures to prevent calcium carbonate scale. The focus of this study was the influence of suspended matter on the membrane clogging.

Fig. 1: PC-Controlled Membrane Test Plant  Fig. 2: Screen-Shot of the PC-control panel
The membrane test procedure works as follows:
At the beginning of a test run the permeate is discharged and the concentrate is recycled back into a small working tank. The water level in the working tank is automatically controlled by adding feed water from the feed water tank. In that manner the test water is concentrated up to the desired concentration level. As soon as the desired volumetric concentration ratio is reached, the concentrate is also discharged, and the test plant is operated continuously at that concentration level and at the desired permeate flux. If scaling occurs, the membrane becomes partly blocked, and so the pressure is automatically increased to keep the permeate flux at a constant value. The test is stopped, when the maximumachievable pressure of 60 bar is reached. Tests have been carried out with and without addition of suspended matter to the feed water.

The first criterion for the performance of the anti-scalant is the total permeate amount produced up to a pressure of 60 bars. In cases where the scaling potential of the test water is low or if an appropriate anti-scaling agent is used, the slope of the pressure increase versus the produced permeate amount serves as second criterion.

For particle measuring a sample of the concentrate is fed into the particle analyzer. Because the concentrate is supersaturated, crystal nucleation and crystal growth start after induction time. This induction time and the development of the particle size distribution are used as further parameters to characterize the performance of the anti-scalant.

The most important components used as antiscalants are phosphonates and polycarboxylates, mainly based on acrylate. All anti-scalants discussed are characterized by a low aquatic and human toxicity, which is a precondition for a widespread application in water treatment. The anti-scalants selected for this study are commercially available.

The results prove that an inhibition of CaCO₃ scale formation on RO membranes is feasible both with phosphonates and phosphorus-free anti-scalants. The individual performance strongly depends on the chemical structure of the anti-scalant.

Studies without addition of suspended matter to the feed water showed a clear ranking of the tested inhibitors. The addition of suspended matter to the feed water led to a partial settling of the particles on the membrane surface. The measured impact of suspended particles on membrane clogging, however, is influenced by numerous parameters, e.g. like particle size distribution, requiring a large number of experiments.