Practical research on TOC removal by ion exchange and the prevention of corrosion - Cases for Water-Link tap water and wastewater effluent after RO treatment

E., De Meyer*, A., Verliefde, B., Peeters*****

*Ghent University, Coupure Links 653, 9000 Ghent, Belgium, Evelyn.DeMeyer@UGent.be
**Ghent University, Coupure Links 653, 9000 Ghent, Belgium, Arne.Verliefde@UGent.be
***Monsanto Europe nv, Scheldelaan 460, 2040 Antwerp, Belgium, Bart.Peeters@Monsanto.com

Central message: The kind of Total Organic Carbon (TOC) does matter

A critical assessment on the removal of TOC from RO effluent by demineralisation, and a clear comparison with the TOC removal from tap water, using the same demineralisation installation was required to address the possible effect on corrosion in boiler systems. More in detail, Monsanto Europe nv wanted to know whether the remaining TOC concentrations in the demineralised water was below the VGB guideline (100 ppb) when the demineralisation unit is fed with RO permeate, in comparison to the TOC concentration when tap water was used as feed water for the demineralisation unit.

Materials and Methods

Lab-scale ion exchange demineralisation set-up

The demineralisation unit of Monsanto consists of a ‘classical’ ion exchange demineralisation, whereby a weak acid cation (WAC) resin is followed by a strong acid cation (SAC) resin, a degassing unit, and a weak basic anion (WBA) and strong basic anion (SBA) resin. This sequence was maintained in the lab-scale set-up, as shown in Figure 1. At the outlet of the SAC column the TOC concentration and the conductivity of the demineralised water were measured continuously with a Sievers 900 online TOC analyser (Colorado, US) and a WTW conductivity probe LR 925/01-P IDS (Weilheim, DE), respectively.

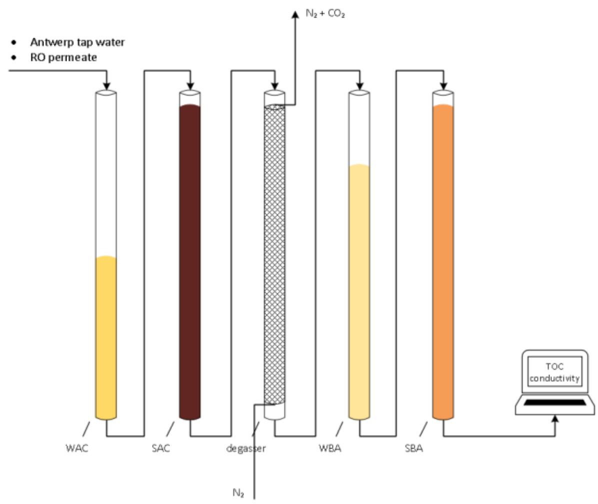

Figure 1. Schematic view of the lab-scale set-up of the demineralisation unit, in which a weak acid cation (WAC) resin is followed by a strong acid cation (SAC) resin, a degassing unit, a weak basic anion (WBA) and strong basic anion (SAC) resin. The TOC concentration and the conductivity of the demineralised water were measured continuously.

Simulation of boiler conditions in a lab-scale set-up

The investigation of the thermal stability, or in other words the susceptibility to thermolysis, of the different water streams was done in a mini-boiler. This lab-scale boiler consisted of 4 stainless steel 316 components (Swagelok, US), moreover a duplicate of SS-800-R-6 and SS-600-6-1. Heat transfer (500 °C) to the lab-scale boiler was accomplished by a Fluidized Sand Bath (FSB-3) containing fine aluminium oxide, which was fluidized by ambient air (Omega, US). A 4838 Parr temperature controller (Parr Instrument Company, US) regulated the FSB temperature and the temperature feedback was provided by a thermocouple.

Results and Discussion

Breakthrough experiments were conducted, for both tap water and RO permeate. During these experiments, the conductivity of the produced demineralised water (the effluent of the SBA column) was lower than 2 µS/cm over the whole runtime. In addition, the concentrations of the most important cations (Na^+ and Ca^{2+}) after the SAC and anions (Cl^-) after the SBA were lower than 0.5% of the initial concentration. The breakthrough curves for tap water and RO permeate are shown in Figure 2.

A rather normal breakthrough behaviour can be seen for tap water, in contrast to almost immediate breakthrough for the RO permeate. Despite the lower TOC concentration in the RO permeate (300 ppb), compared to tap water (1.2 ppm), the TOC compounds present in the RO permeate appeared to only have very low affinity for the ion exchange resins. Closer investigation of the LC-OCD analysis gave a plausible reason for this phenomenon. As the largest part of TOC in the RO permeate were Low Molecular Weight Neutrals (LMWN), the TOC affinity with the charged ion exchange resins was indeed expected to be low. Therefore, early breakthrough was observed for the RO permeate, while the tap water contained less LMWN and more charged TOC compounds (humic and fulvic acids), resulting in a more gradual breakthrough, in relation to the exhaustion of the resins.

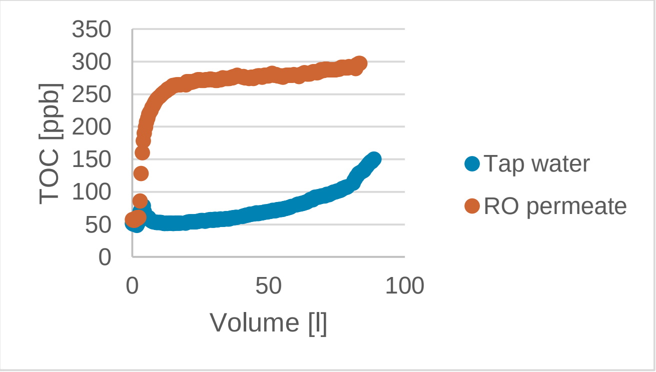

Figure 2. The TOC breakthrough curves for tap water and RO permeate

In terms of organic acid formation under boiler conditions, RO permeate gave the same results as treated AWW water, 9 ppb formate and 25 ppb acetate were formed. The only disadvantage of using RO permeate directly is the high Cl^- concentration, which can cause pitting corrosion on metal surfaces. When treated RO permeate was used only formate was formed (11 ppb). Based on these preliminary findings, RO permeate treated with ion exchange leaded to less formation of organic acids under boiler conditions, compared to the treated AWW water. Despite the fact that the RO permeate treated by ion exchange had a higher TOC concentration (155 ppb compared to 55 ppb for the AWW tap water), the treated RO permeate leaded to less formation of organic acids under boiler conditions (500 °C, 60 bar). These results show that the questioning of the VGB TOC guideline of 100 ppb is well founded. In practice, it is not only about how much TOC is present in the boiler feed water, more important it is about what kind of TOC is present.

Contributions of the work

- The VGB guideline for TOC concentration in boiler feed water is 100 ppb, but this parameter doesn't include the kind of TOC.
- This research shows that the kind of TOC is of most important, in contrast with the concentration.
- As expected different TOC leads to a different pattern in organic acid formation under boiler conditions.
- If generalization is possible, this can lead to less costly demineralization technologies for the production of industrial boiler feed water, all depending on the incoming TOC composition.
- More different water qualities will be tested in the future.