Desalination of brackish inland surface water using nanofiltration: Fouling control and water quality improvements

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Reverse osmosis (RO) of seawater and brackish groundwater are two options often discussed to combat drinking water shortages arising from persistent drought and population growth. In contrast to the high salinities of these waters, there are several lakes with lower total dissolved solids concentration in the range 2,000-5,000 mg/L, which can potentially be desalinated using nanofiltration (NF). Since NF membranes are operated at lower pressures and higher flux they are more economically viable than RO. However, the higher concentrations of colloids (i.e. turbidity), organic matter (i.e. dissolved organic carbon, DOC), and microorganisms in brackish surface waters and our limited experience with desalinating such waters present significant challenges to NF implementation, especially with respect to pretreatment.

The principal objectives of this research are to identify dominant foulants and systematically elucidate NF fouling mechanisms by thoroughly investigating interactions of various feed water constituents with the membrane surface to select appropriate pretreatment. We evaluate microfiltration (MF) alone and electrocoagulation-MF as pretreatment options for the NF270 membrane. Experiments were performed using water samples from the Washita Basin in West-Central Oklahoma (i.e. Foss Reservoir), which serves over 40,000 people. Results were benchmarked with synthetic feed water to isolate precipitative, organic, and colloidal fouling. Membrane morphology, organic functionalities and elemental composition were analyzed using scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS), atomic force microscopy (AFM), Fourier Transform Infrared (FTIR) spectroscopy, and X-ray Photoelectron Spectroscopy (XPS).

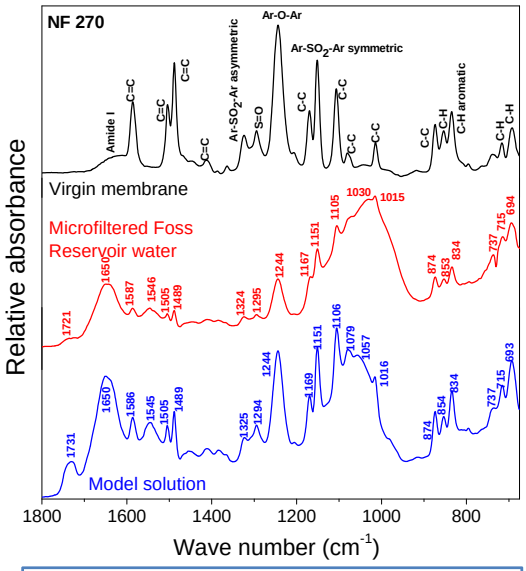


Figure 1. *ATR-FTIR spectra of membranes before and after NF of model solution and pretreated natural water from Foss Reservoir*

As shown in **Figure 1**, the virgin membrane exhibited bands typical of thin film composite polyamide membranes. The sharp and prominent peaks at 1151, 1243, and 1323 cm^{-1} corresponds respectively to Ar-SO_2-Ar, Ar-O-Ar, and asymmetric SO_2 stretching vibrations from the polysulfone support layer. The C=C aromatic in-plane ring bend stretching vibrations at 1586, 1504, and 1488 cm^{-1} are also attributed to the support layer. Following NF of microfiltered Foss Reservoir water, the virgin membrane characteristic peaks were either attenuated or reduced in intensities as a result of foulant deposition. The more intense amide I peak (vC=O + δC-N + δN-H) and the appearance of amide II peak (δN-H + vC-N) which was previously absent in the virgin membrane might indicate the presence of proteinaceous compounds.

The elemental composition of virgin and fouled membranes was obtained using survey and high-resolution XPS scans. The C1s peak in virgin membranes was deconvoluted into three components whereas the O1s was resolved into two peaks. The changes in C1s features were not very significant suggesting that only a thin foulant layer was formed. An increase in the area percentage of the peak around 286 eV indicates an increase in the number of C-(O, N, OH) bond on the nanofilter surface that might come from organics (proteins, polysaccharides, and humics) and/or carbonates. The increase in the number of carbonyl and carboxyl groups as indicated by the increase in peak at ~288.1 eV and the appearance of a small peak at ~288.9 eV might also originate from carbonates and/or organics.

As expected, natural organic matter and major divalent ions including Ca, Mg, Sr, and SO_4^{2-} were highly rejected (> 99%). The very high rejection of SO_4^{2-} is attributed to anion repulsion since the membrane is known to be negatively charged at the operating pH of 7.8. Interestingly, the dominant monovalent anion, i.e. chloride, was negatively rejected, which is attributed to its preferential transport across the membrane due to the Donnan effect necessary to maintain electroneutrality. Chloride ions compensate for the very high removal of sulfate (due to electrostatic ion-membrane repulsion) and correspondingly lower removals of cations (due to electrostatic ion-membrane attraction). More details, will be presented at the time of the conference, including fouling control results from electrocoagulation pretreatment as well as electron and force microscopy and high resolution XPS scans of membrane surfaces.