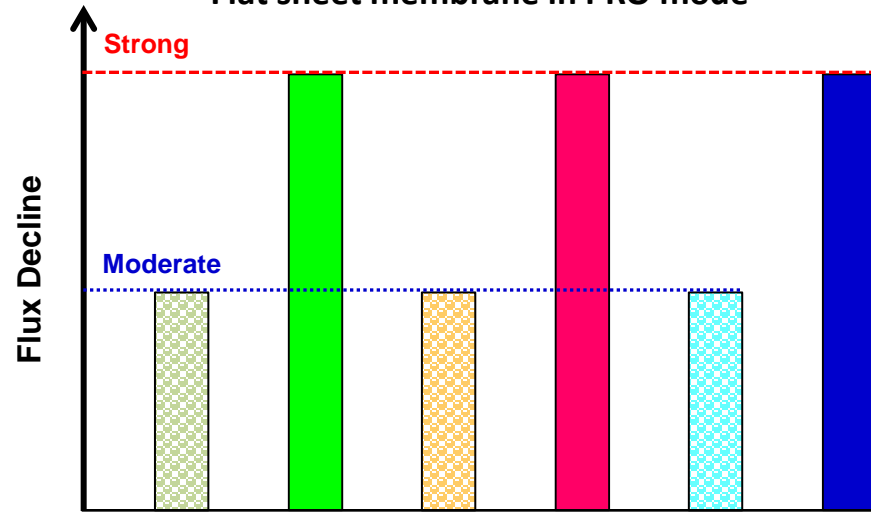


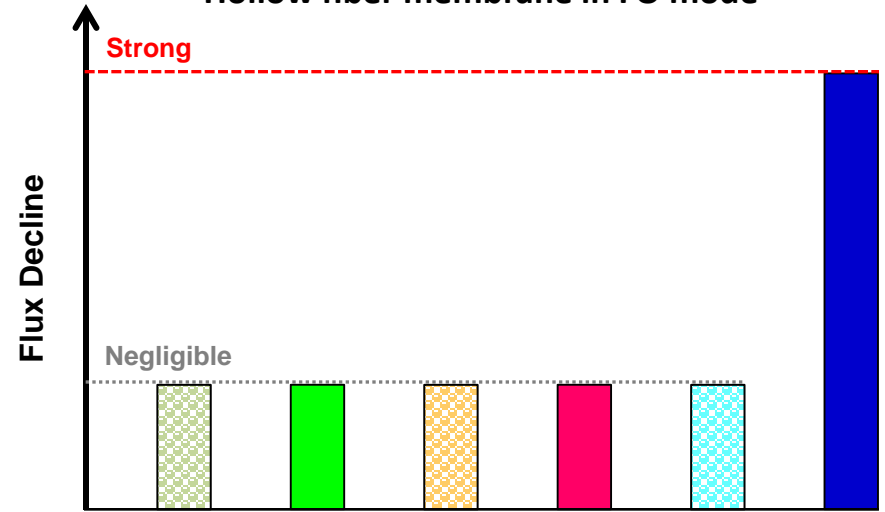
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| Title | Impact of intrinsic properties of foulants on membrane performance in osmotic desalination applications(Figures) |
| Author(s) | Arkhangelsky, Elizabeth; Lay, Susan Sulaiman; Wicaksana, Filicia; Al-Rabiah, Abdulrahman A.; Al-Zahrani, Saeed M.; Wang, Rong |
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Flat sheet membrane in PRO mode





Hollow fiber membrane in FO mode





 *Big hydrodynamic diameter foulant*

 *Negatively charged foulant*

 *Non-viscous foulant*

 *Small hydrodynamic diameter foulant*

 *Positively charged foulant*

 *Viscous foulant*

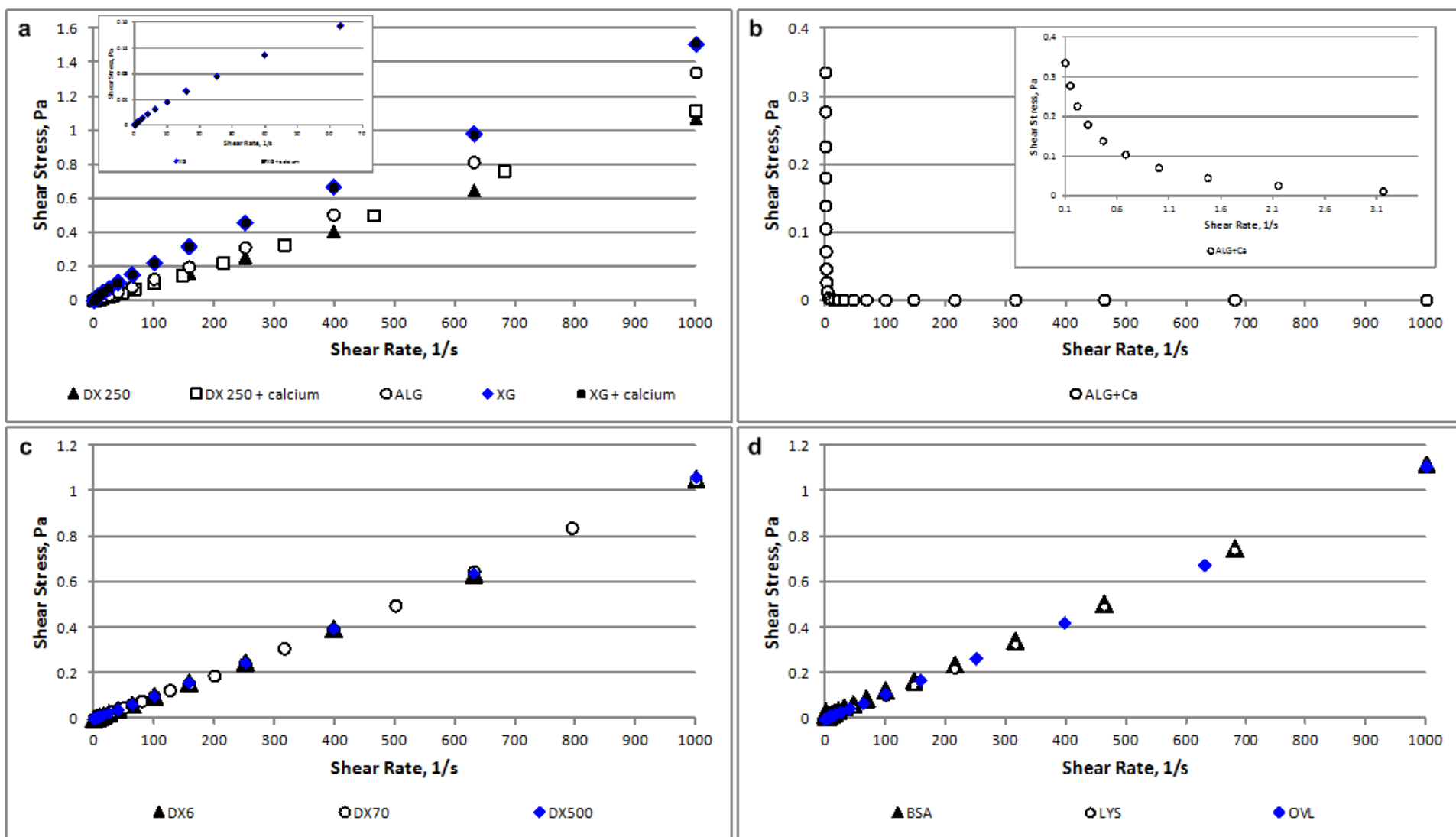


Figure 1. Rheological behavior of polysaccharides and proteins: (a) DX 250, DX 250 + CaCl₂, ALG, XG, XG + CaCl₂; (inset: XG and XG + CaCl₂ at 0.1 – 70 s⁻¹ shear rate range); (b) ALG + CaCl₂; (inset: at 0.1 – 3 s⁻¹ shear rate range); (c) DX 6, DX 70, DX 500; (d) BSA, LYS, OVL. Experimental conditions: 200 ppm of foulant, 10 mM NaCl, 3 mM CaCl₂, temperature 23 °C.

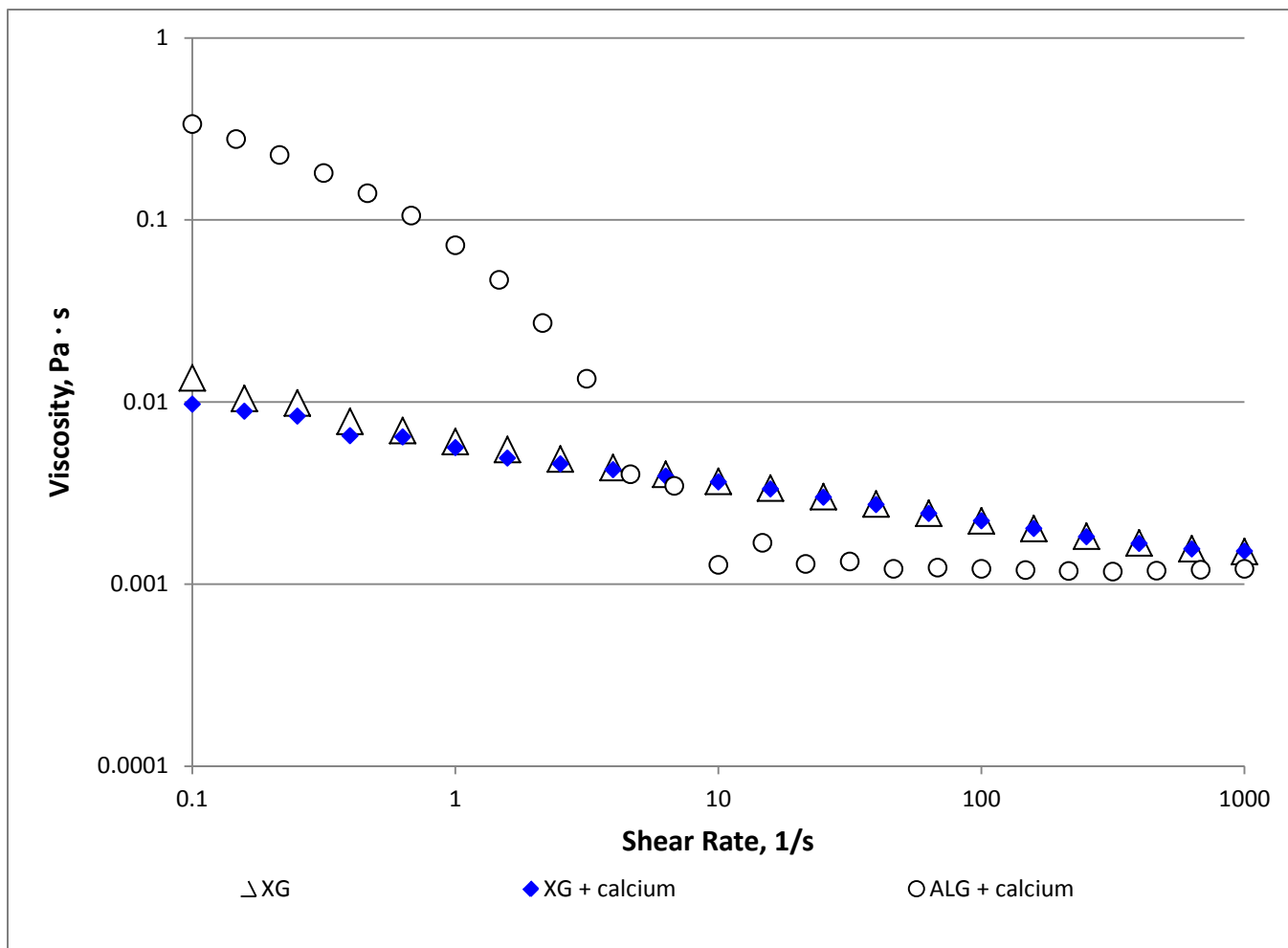


Figure 2. Viscosity as a function of shear rate for non-Newtonian foulant solutions. Experimental conditions: 200 ppm of foulant, 10 mM NaCl, 3 mM CaCl₂, temperature 23 °C.

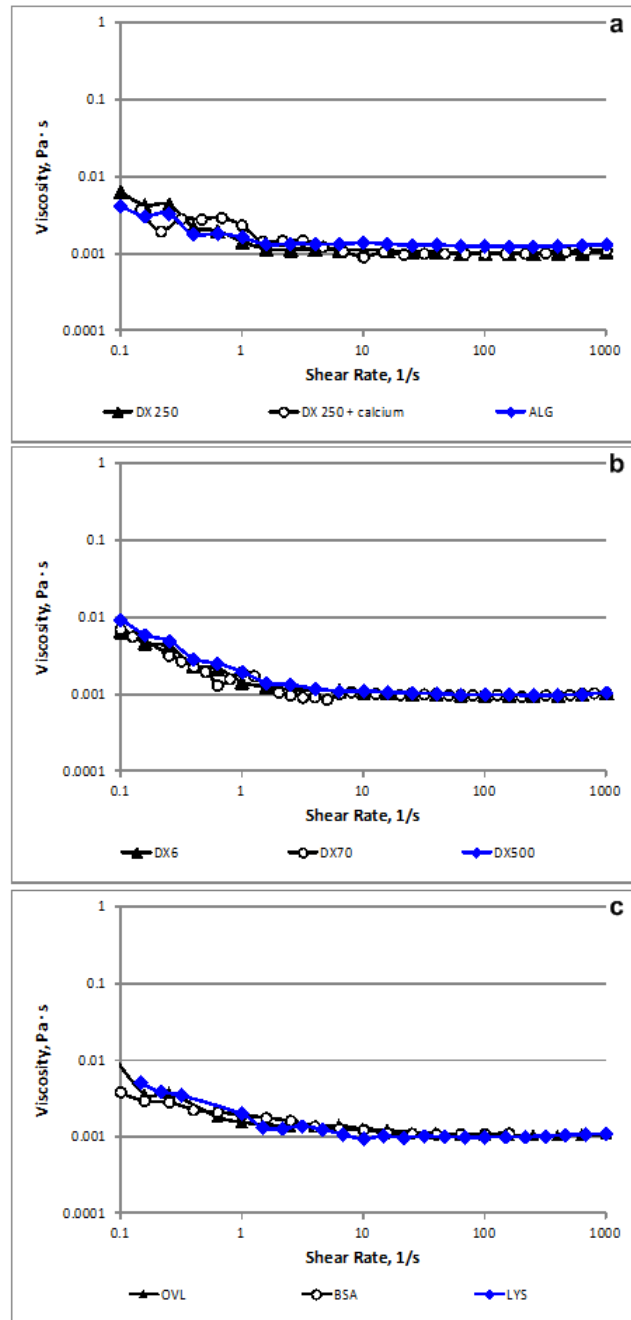


Figure 3. Viscosity as a function of shear rate for various foulant solutions. Experimental conditions: 200 ppm of foulant, 10 mM NaCl, 3 mM CaCl₂, temperature 23 °C.

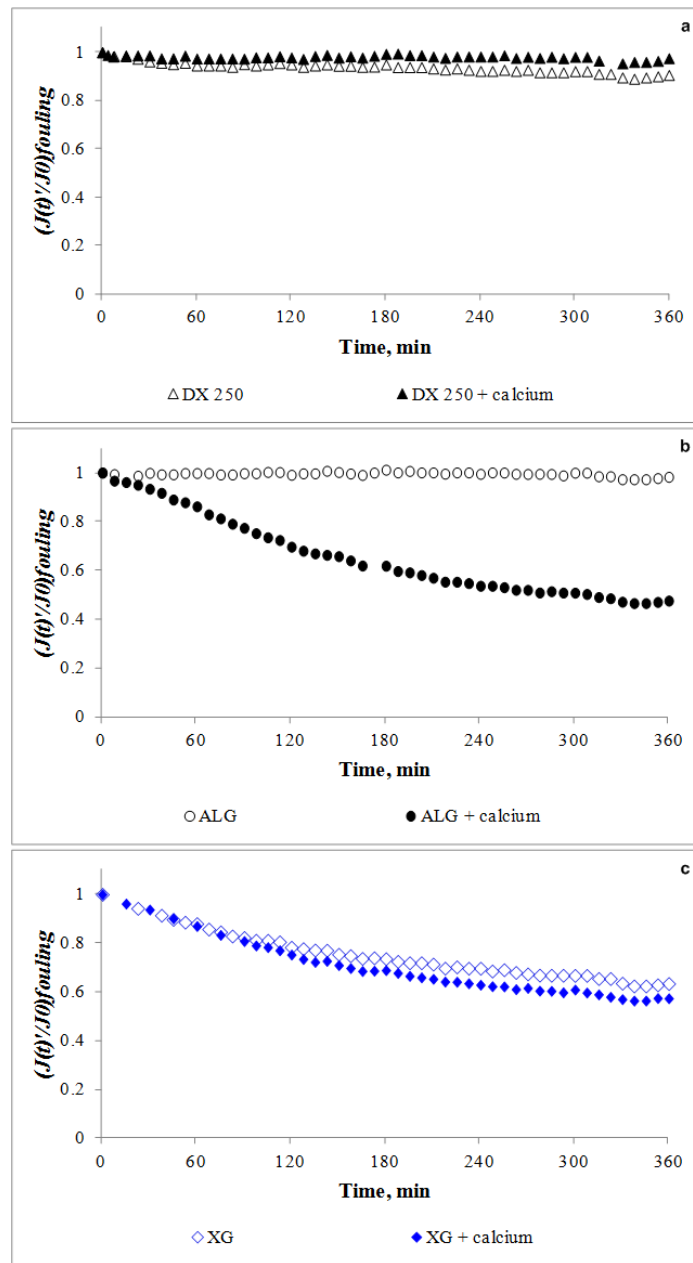


Figure 4. The effect of calcium addition on the performance of hollow fiber membrane in FO mode with (a) DX 250, (b) ALG and (c) XG. Feed solution contained 10 mM NaCl + 200 mg/L foulant + 0 or 3 mM CaCl₂. Experimental conditions: cross-flow velocity 6.5 cm/s; draw solution 2.25 M NaCl; pH 6.25-6.5; temperature 23 °C.

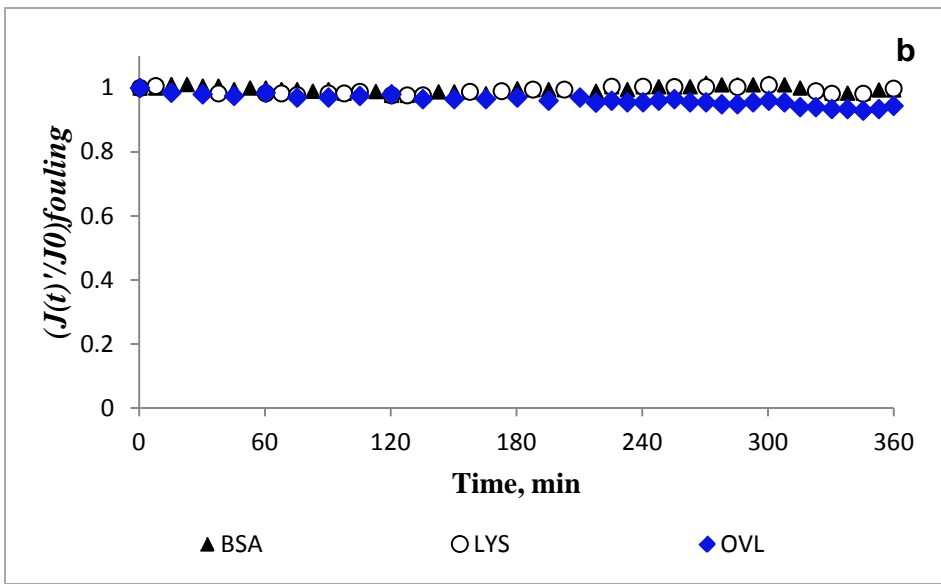
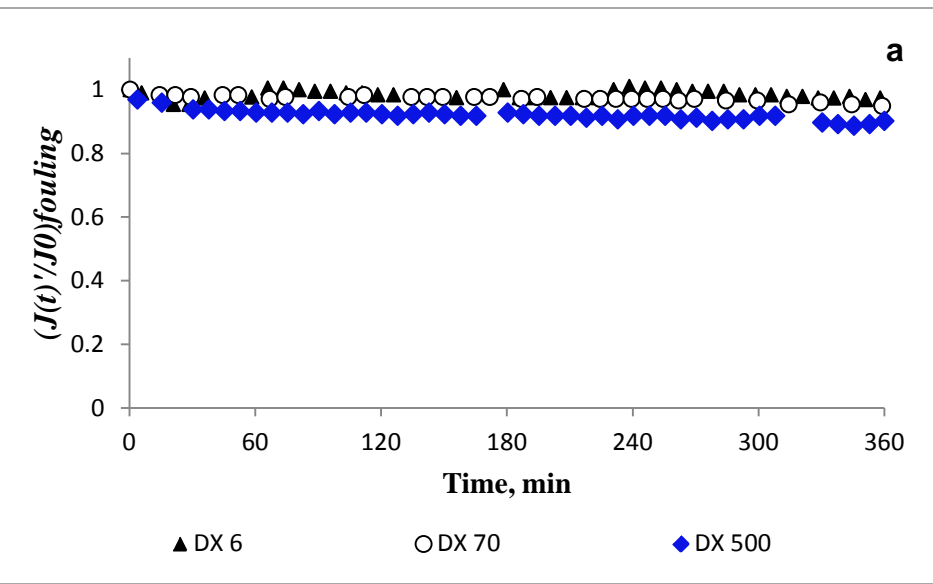


Figure 5. Effect of (a) DX 6, DX 70, DX 500 and (b) BSA, LYS, OVL on hollow fiber membrane performances in FO mode. Feed solution contained 10 mM NaCl + 200 mg/L foulant. Experimental conditions: cross-flow velocity 6.5 cm/s; draw solution 2.25 M NaCl; pH 6.25-6.5; temperature 23 °C.

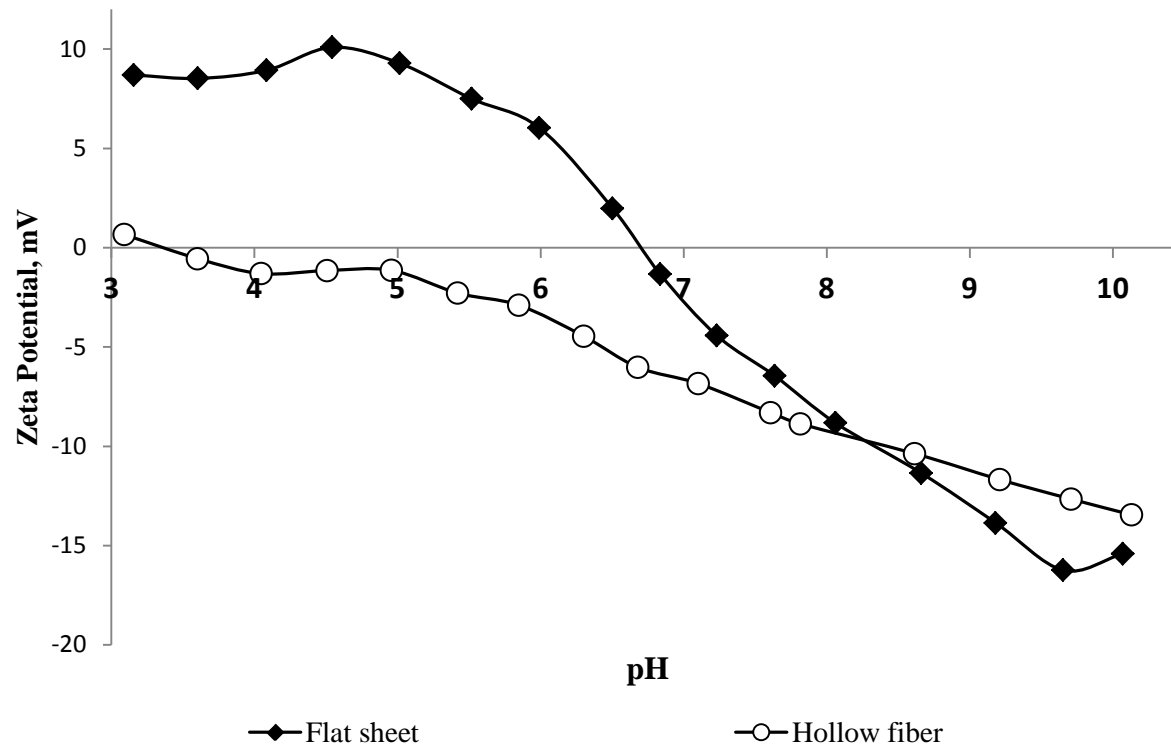


Figure 6. Zeta potential of flat sheet and hollow fiber membranes in 10 mM KCl as a function of pH.

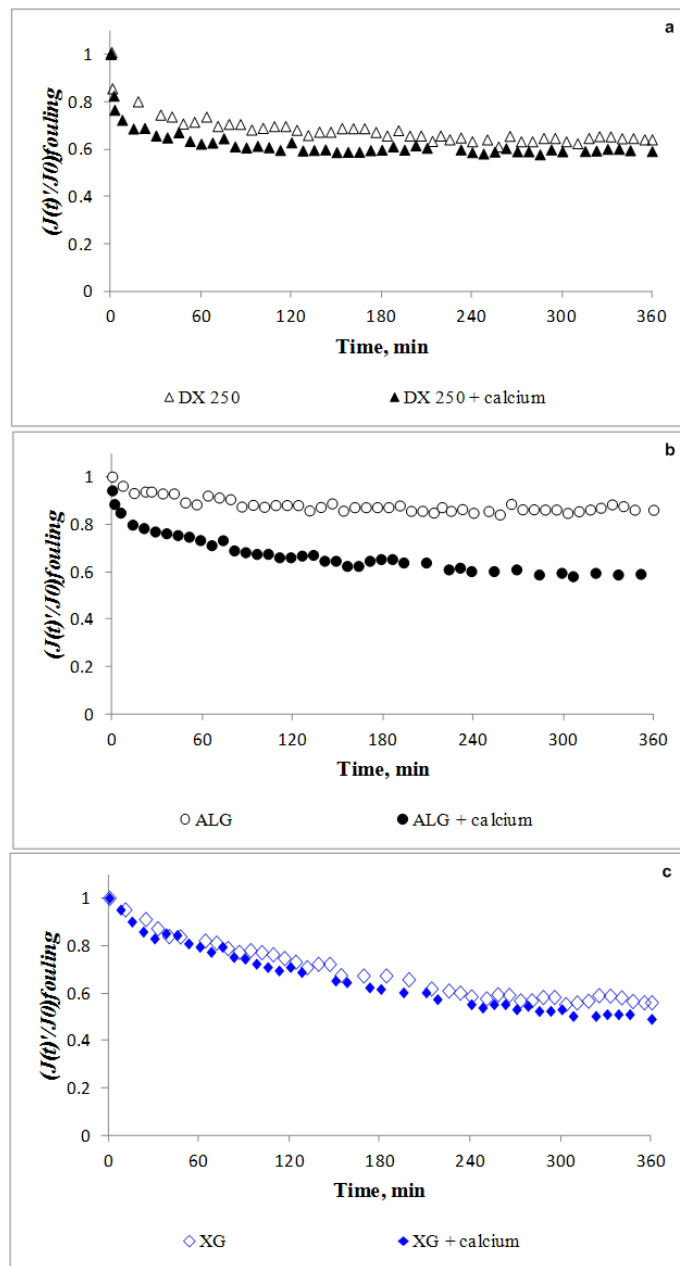


Figure 7. The effect of calcium addition on the performance of flat sheet membrane in PRO mode with (a) DX 250, (b) ALG and (c) XG. Feed solution contained 10 mM NaCl + 200 mg/L foulant + 0 or 3 mM CaCl₂. Experimental conditions: cross-flow velocity 6.5 cm/s; draw solution 2.25 M NaCl; pH 6.25-6.5; temperature 23 °C.

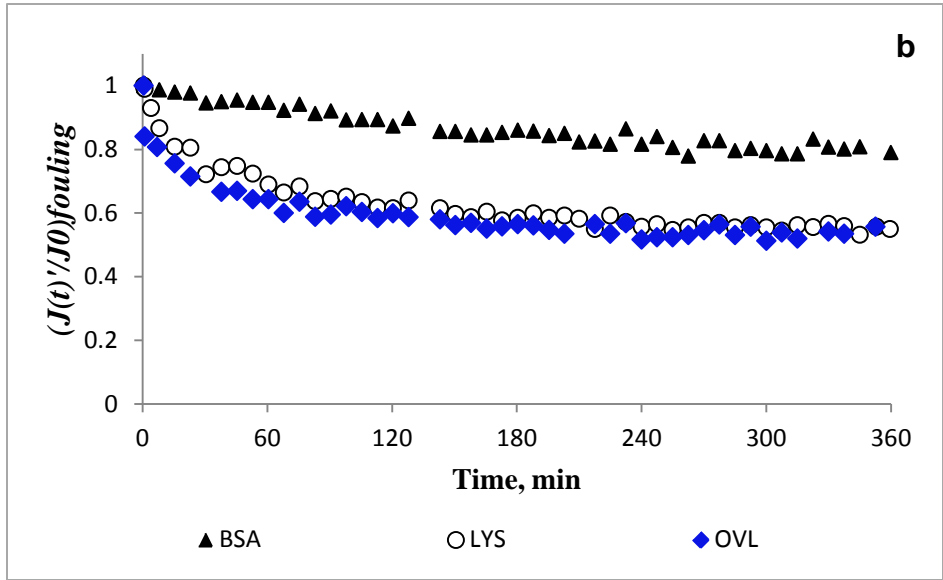
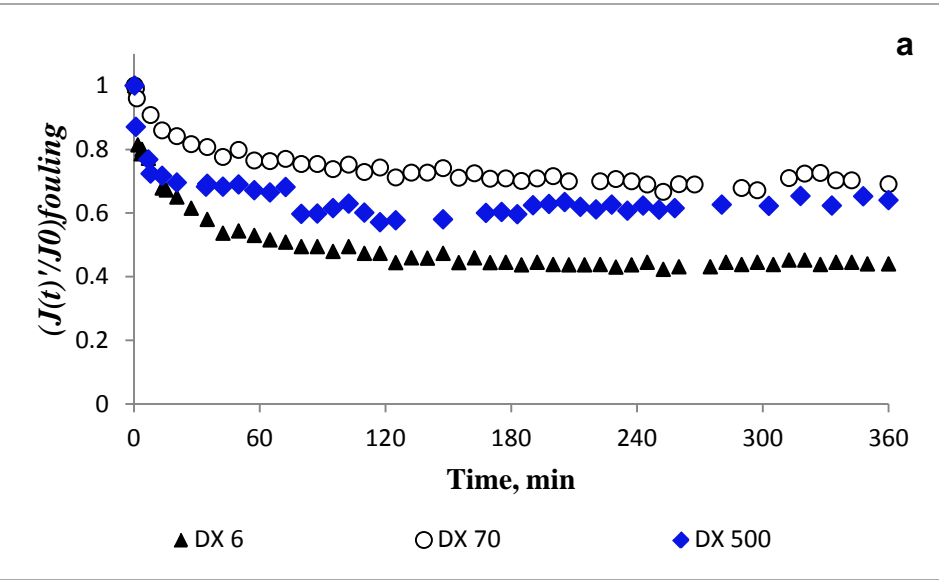


Figure 8. Effect of (a) DX 6, DX 70, DX 500 and (b) BSA, LYS, OVL on flat sheet membrane performances in PRO mode. Feed solution contained 10 mM NaCl + 200 mg/L foulant. Experimental conditions: cross-flow velocity 6.5 cm/s; draw solution 3 M NaCl; pH 6.25-6.5; temperature 23 °C.

Table 1. Characteristics of FO membranes.

| Configuration | Flat sheet membrane | Hollow fiber membrane |
|---|----------------------------|------------------------------|
| Active layer material | cellulose triacetate | polyamide |
| Support layer material | cellulose triacetate | polyether sulfone |
| Thickness, μm | 45[47] | 205 [22] |
| Support pore size, nm | 20,000 – 40,000 [48] | --- |
| Contact angle of support layer, $^\circ$ | 87 [11] | --- |
| Contact angle of active layer, $^\circ$ | --- | 77 ^a |
| Water permeability, L/m ² -h-atm | 0.74 ^b | 3.5 ^b |
| NaCl permeability, L/m ² -h | 0.08 ^b | 0.22 ^b |
| NaCl Rejection, % | 88 ^b | 95 ^b |
| Structural parameter, m | 3.93×10^{-4} [2] | 5.5×10^{-4} [22] |

^a Was measured for flat sheet polyamide-polysulfone membrane with the sessile drop method, using a goniometer (Contact Angle System OCA, DataPhysics Instruments GmbH, Germany).

^b The membranes were tested under RO mode to determine the salt rejection, pure water and salt permeability. The tests were performed under the condition of cross-flow with a flow rate of 450 ml/min at 1 bar pressure and room temperature of 23 °C. The salt rejection was determined using feed water containing 500 ppm NaCl.

Table 2. Foulants used in the study.

| Foulant Designation | Foulant Name | MW, kDa | Manufacturer | Origin |
|----------------------------|----------------------|----------------|----------------------------------|------------------------------------|
| XG | Xanthan Gum | --- | Sigma-Aldrich | from <i>Xanthomonas campestris</i> |
| ALG | Sodium Alginate | --- | Hayashi Pure Chemical Industries | --- |
| DX 6 | Dextran | 6 | Fluka | from <i>Leuconostoc</i> spp |
| DX 70 | Dextran | 70 | Sigma-Aldrich | from <i>Leuconostoc</i> spp |
| DX 250 | Dextran | 200-300 | MP Biomedicals | --- |
| DX 500 | Dextran | 500 | Sigma-Aldrich | from <i>Leuconostoc</i> spp |
| BSA | Bovine Serum Albumin | 66 | Sigma-Aldrich | from bovine serum |
| LYS | Lysozyme | 14 | Fluka | from chicken egg white |
| OVL | Ovalbumin | 44 | Sigma-Aldrich | from chicken egg white |

Table 3. Shear stress, hydrodynamic diameter and zeta potential of studied polysaccharides and proteins.

| Foulant | Shear stress of Newtonian fluids at 520/580 s ⁻¹ shear rate, Pa | | Hydrodynamic diameter, nm | | Zeta potential, mV | |
|---------|---|--------------|---------------------------|--------------|--------------------|--------------|
| | No Calcium | With Calcium | No Calcium | With Calcium | No Calcium | With Calcium |
| DX 250 | 0.57/0.64 | 0.52/0.58 | 11 | 14 | -2 | -2 |
| ALG | 0.67/0.75 | | 15 | 57 | -45 | -29 |
| XG | | | 13 | 34 | -50 | -29 |
| DX 6 | 0.52/0.58 | | 3 | | -9 | |
| DX 70 | 0.52/0.58 | | 7 | | -17 | |
| DX 500 | 0.52/0.58 | | 15 | | -3 | |
| BSA | 0.59/0.65 | | 5 | | -16 | |
| LYS | 0.57/0.63 | | 3 | | 14 | |
| OVL | 0.57/0.64 | | 6 | | -7 | |

Experimental conditions during shear stress, hydrodynamic diameter and zeta potential measurements: 200 ppm of foulant, 10 mM NaCl, 3 mM CaCl₂, pH 6.25-6.5, temperature 23 °C.

Table 4. Flux declines due to fouling measured at the end of experiments.

| Feed Solution | Flux decline due to fouling at the end of experiment, % | | | |
|---------------|---|--------------|-------------------------|--------------|
| | Flat sheet membrane in PRO mode | | Hollow fiber in FO mode | |
| | No Calcium | With Calcium | No Calcium | With Calcium |
| DX 250 | 36 | 42 | 9 | 2 |
| ALG | 14 | 42 | 2 | 52 |
| XG | 44 | 51 | 37 | 43 |
| DX 6 | 56 | | 3 | |
| DX 70 | 31 | | 5 | |
| DX 500 | 36 | | 10 | |
| BSA | 21 | | 0 | |
| LYS | 45 | | 0 | |
| OVL | 44 | | 6 | |