Recovery of valuable polymeric solutions by lowering the salinity with electrodialysis

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Motivation

Every year, millions of cubic meters of polymer-flooding produced water (PFPW) are generated in the world, and the figure is likely to keep increasing. Just in the Daqing field in China, the amount is $6x10^7$ m^3 of PFPW/year [1], equivalent to the volume of 24,000 Olympic pools. This water results from applying enhanced oil recovery (EOR) techniques, and in general contains a viscosifying polymer, varying amounts of salts, solids, and some emulsified oil, a combination that makes its treatment for reuse or disposal very challenging. Even after removing the oil and solids, the high salt content makes the mixture unsuitable for reuse in EOR. This is because the swelling degree of the polymer decreases with increasing salinity of the solution, consequently lowering its viscosifying effect.

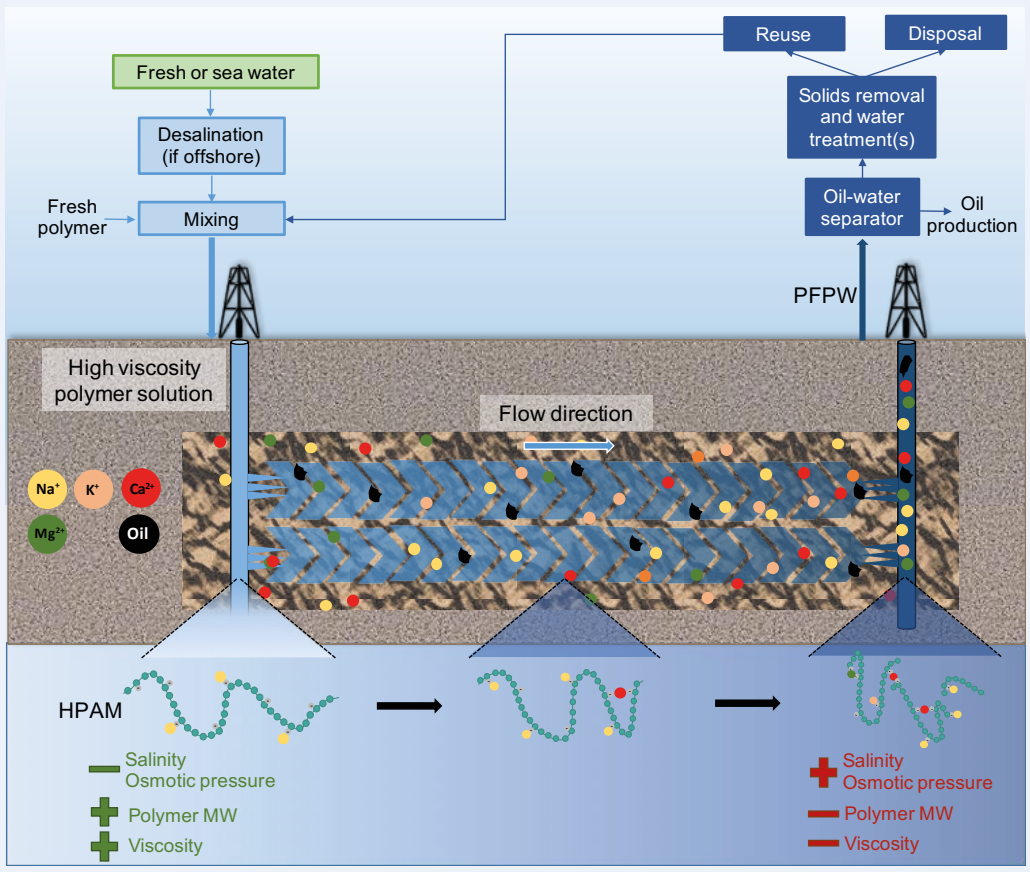


Fig 1. Origin of PFPW. In EOR, large volumes of water viscosified with polymers are pumped through an injector well in order to sweep the oil and/or gas and increase their recovery. The PFPW is later recovered still containing the polymer, but also high amounts of salts, solids and some emulsified oil.

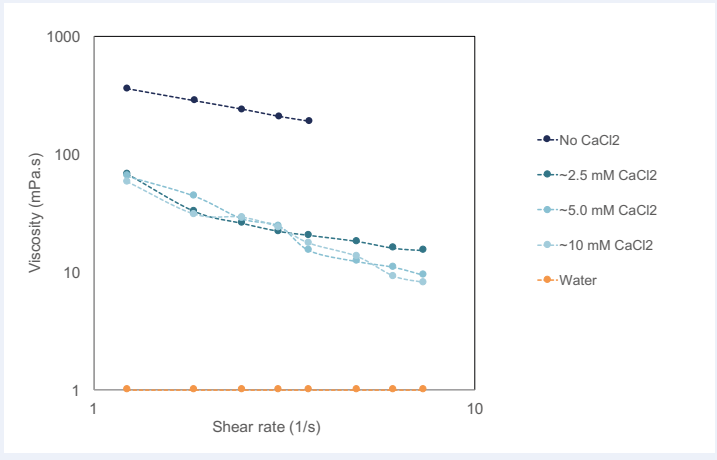
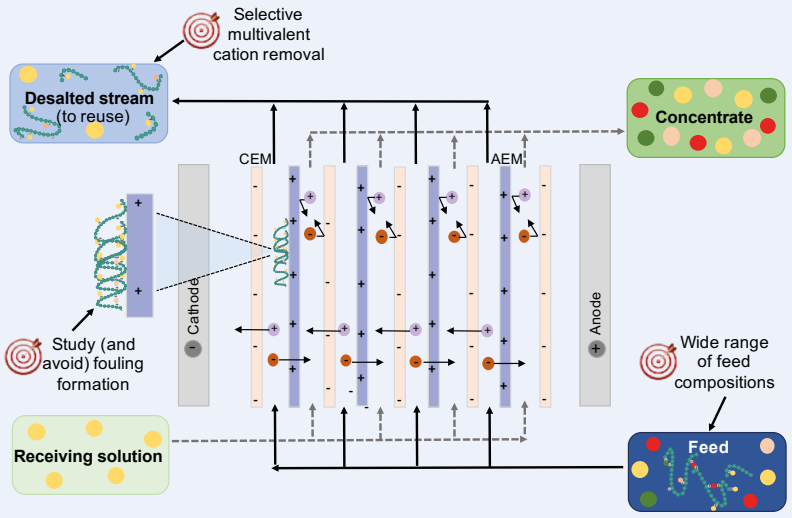


Fig 2. Viscosity curves of HPAM solutions (1.0 g/L) with varying salt content (CaCl2). The higher the salt content, the lower the viscosity.



Electrodialysis, a salt selective technology that relies on ion-exchange membranes to desalinate streams, will be employed during this project to reduce the salinity of the PFPW stream and, consequently, restore the expanded state of the polymer. This will increase the viscosity of the solution and lead to a reduction in the consumption of fresh water and polymer in EOR operation.

Technological challenges

1. **Produced water is a complex mixture.** The types and amounts of salts, oily compounds, and even polymer vary from location to location. Although the most common EOR polymer is partially hydrolyzed polyacrylamide (HPAM), many other types of polymers are being developed and employed.
2. **Selective removal of multivalent cations.** Since the viscosity of HPAM solutions is much more affected by the presence of multivalent cations when compared to monovalent cations[2], their selective removal is highly desirable.
3. **Membrane fouling.** Due to the intrinsic negative charge of HPAM, it could have electrostatic interactions with the positively charged anion-exchange membrane (AEM)[3], causing fouling problems. In adition, concentration polarization may be affected by the viscous fluid layers near the membrane.

Research goal

The main research objective is to investigate the desalination process of synthetic PFPW by electrodialysis, placing special attention in understanding the membrane fouling mechanism. In order to achieve this, three main lines will be followed:

- Physical chemical characterization of the polymer in different salt solutions and its interaction with the positively charged surface of the AEM.
- Process and membrane characterization.
- Optimal electrodialysis cell design and operation for desalination of polymeric solutions, based on the insights of the two aforementioned research lines.

[1] Guolin et al. (2010) Desalination, 264(3), 214–219.
[2] Jing, G. et al. (2011) Desalination and Water Treatment, 25(1-3), 71–77
[3] Guo et al. (2014). Desalination, 346(0), 46-53

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