

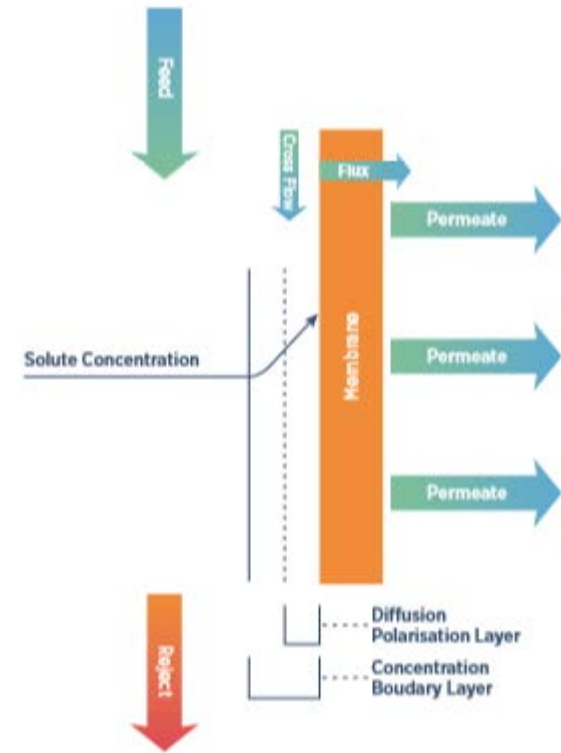
Technical Fundamentals of EIS

CMS Innovations Pty Limited

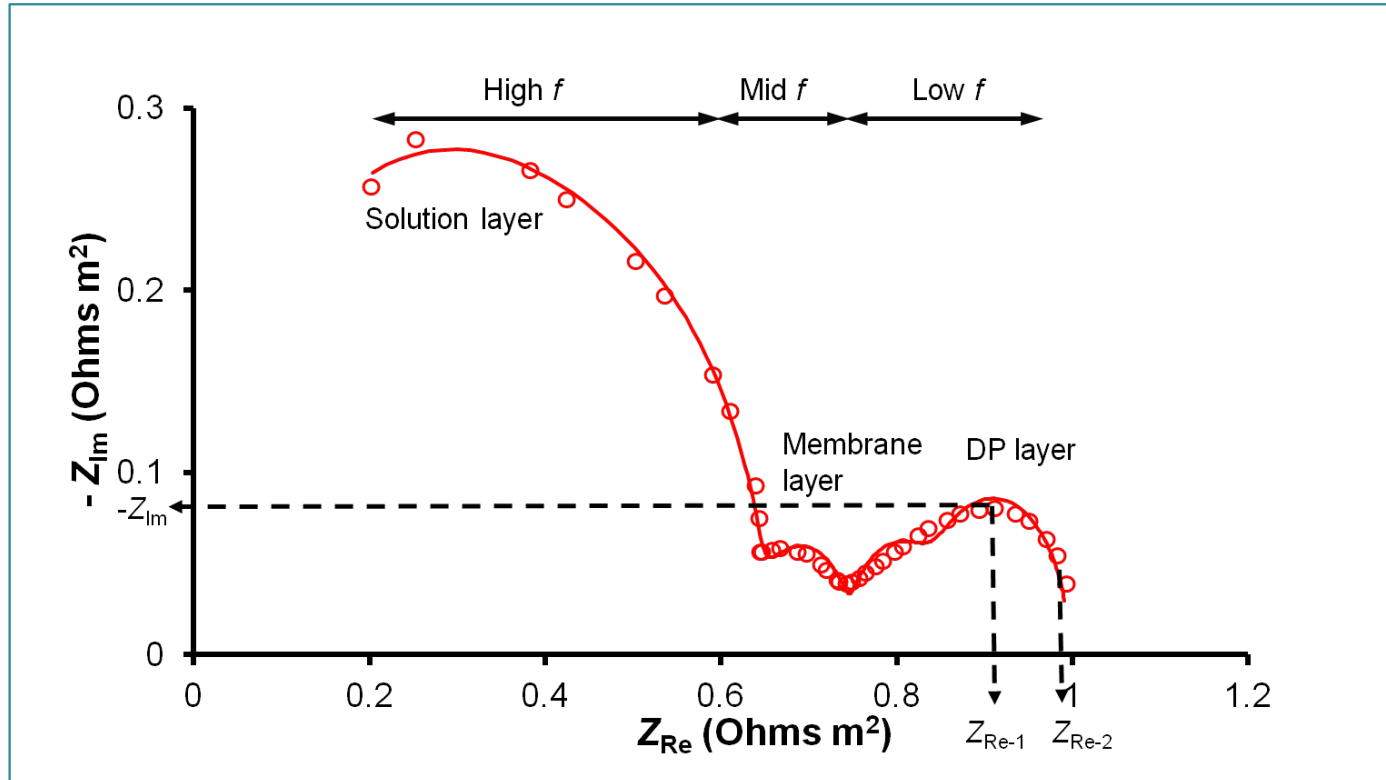
November 2016

Introduction to Electrical Impedance Spectroscopy

- Electrical properties of Diffusion Polarisation (DP) Layer are detectable at very low frequencies
- DP Layer only exists when current and flux applied
- Changes in Capacitance and Conductance in the DP Layer are caused by change in the form of the material at membrane surface
- Onset of incipient fouling indicated by significant change in trend (i.e. predictive)
- Conductance of DP Layer is G_{dp}
- Impedance of DP Layer is Z_{dp}

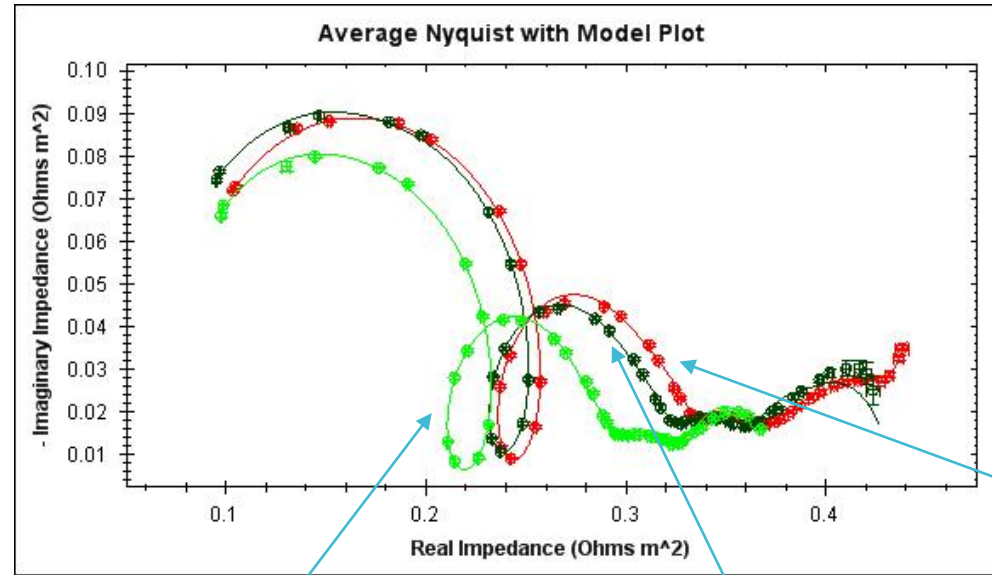


EIS Membrane Signature Overview



- Nyquist plot of imaginary vs real impedance (Z_{Im} and Z_{Re})
- Diffusion Polarisation layer identified in response at low frequencies
- Changes to Impedance of DP layer reveal physical changes to membrane surface

Signatures in Early Stages of Filtration



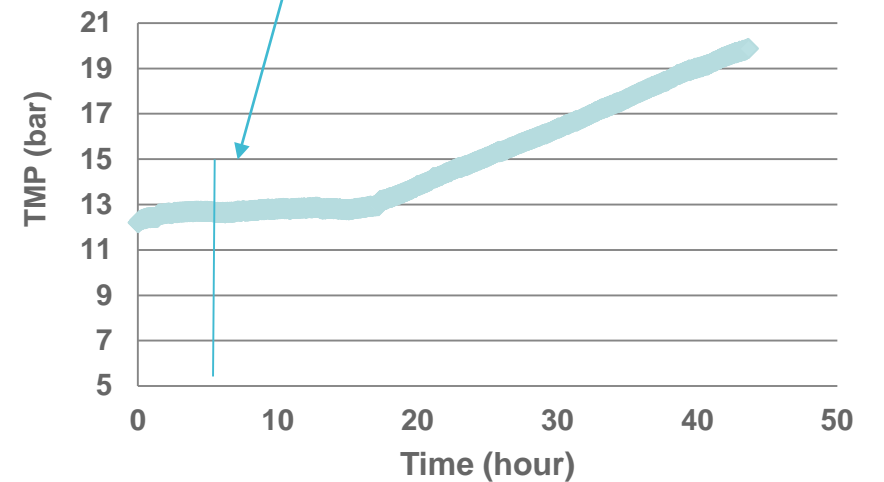
Saline – No Silica

2 Hours Silica

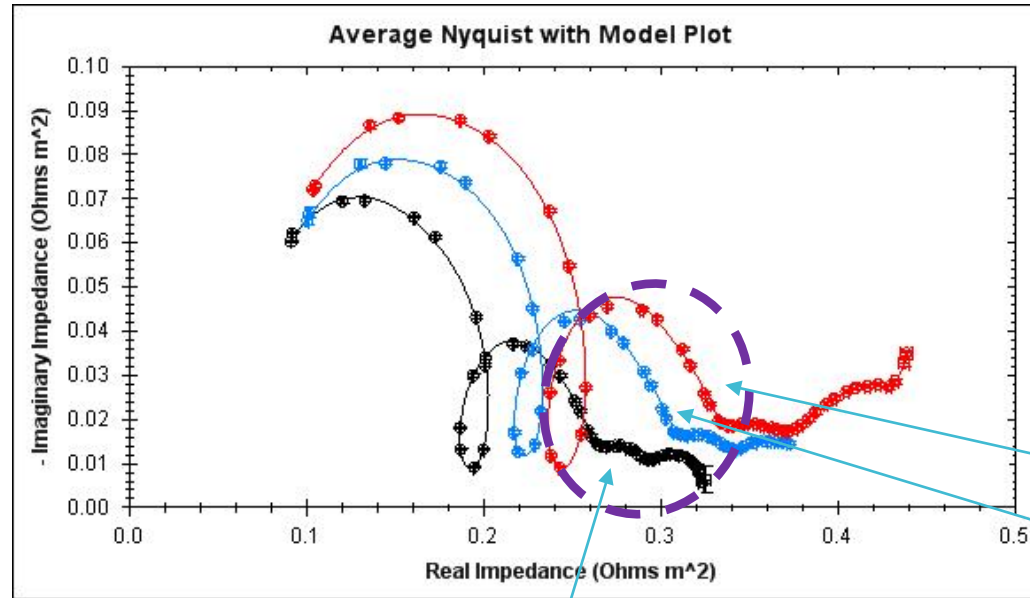
- Impedance curve shifts to the right during early stages of filtration

5 Hours Silica

- Induced inorganic fouling
- Impedance changes caused by silica induced changes to Diffusion Polarisation layer



Signatures of Membrane Fouling

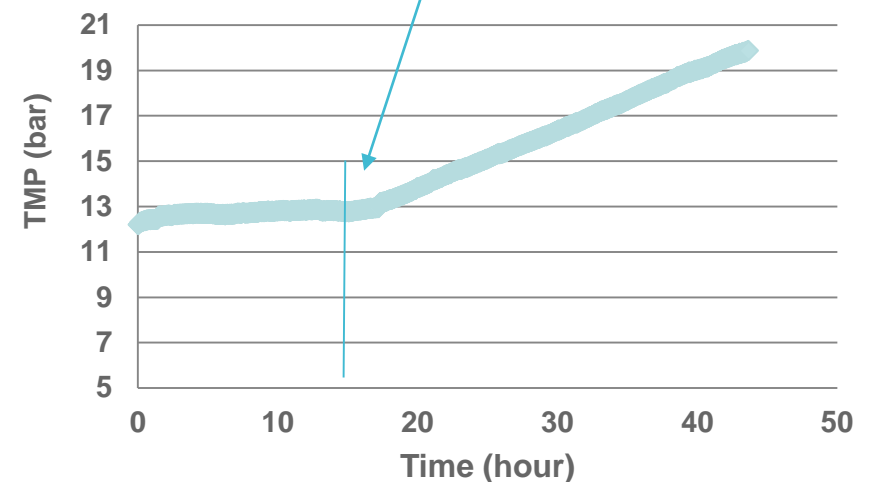


- Impedance shift reverses direction between hours 5 and 15
- Identifies onset of Cake Enhanced Concentration Polarisation

5 Hours Silica
15 Hours Silica

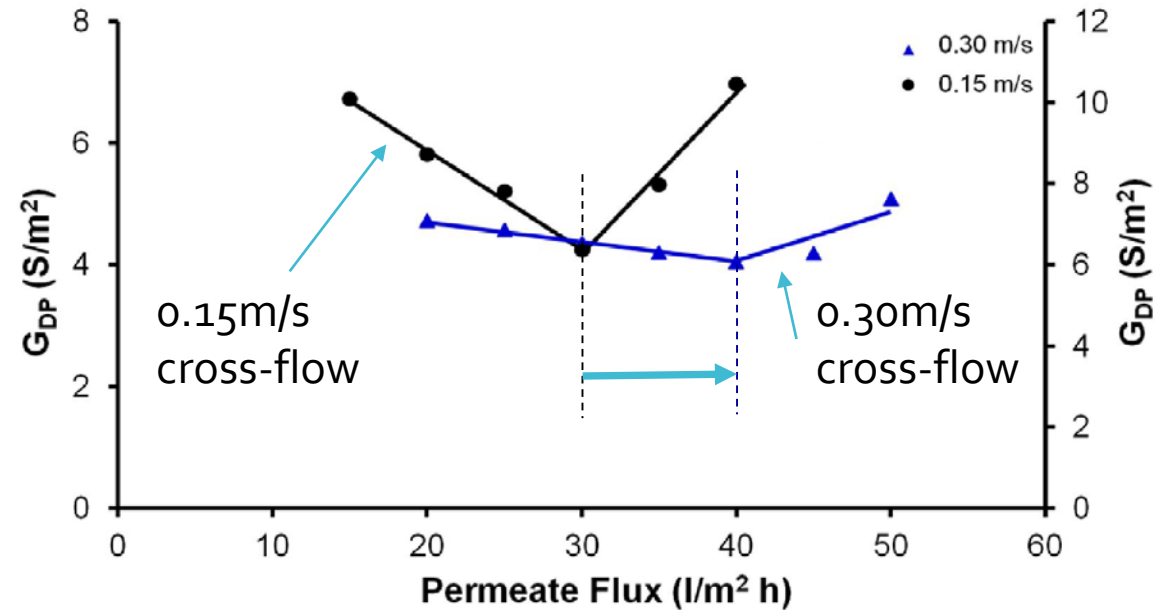
48 Hours Silica

- EIS signature changes well ahead of fouling revealed by Trans Membrane Pressure



EIS to Identify Threshold Flux with Inorganic Foulant

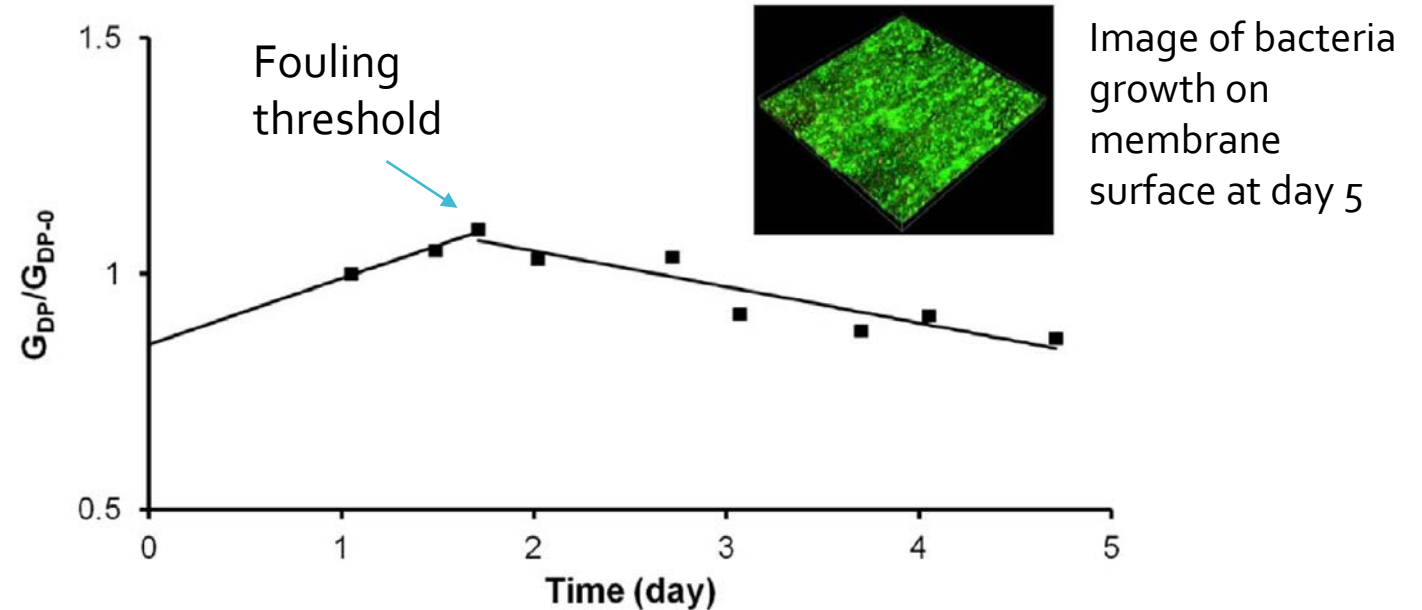
Inorganic Threshold Flux Detection



- Electrical Conductance (G_{dp}) Inflexion marks Threshold Flux
- Threshold Flux increases with increased cross-flow velocity
- RO feed: 200 ppm silica with 2000 ppm NaCl

EIS to Identify Biofouling

Detection of Biofouling



- Electrical Conductance (G_{dp}) response to bacteria growth with addition of Nutrient Broth (NB)
- Different Biofouling and Inorganic fouling responses allow discrete detection
- Cross-flow 0.15 m/s; Flux 30 m^2/hr ; Feed 24 mg/l NB, 2000 ppm NaCl