Queen Mary
University of London

Membrane fouling and filtercake formation during static microfiltration harvesting of microalgae using thin glass fibre filters

16th InterPore Annual meeting

PhD Student: **Jincheng Wu**

Supervisors: Dr Edo Boek, Dr Gerry Meeten, Dr Timothy G.J. Jones, Dr Neil Cagney

Centre for Sustainable Engineering

School of Engineering and Materials Science (SEMS)

Background

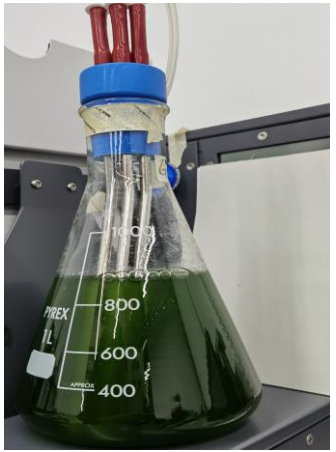
Algem Photobioreactors

Problem:

low microalgal biomass yields (max 10 g/L) in autotrophic **cultivation**.

Challenge:

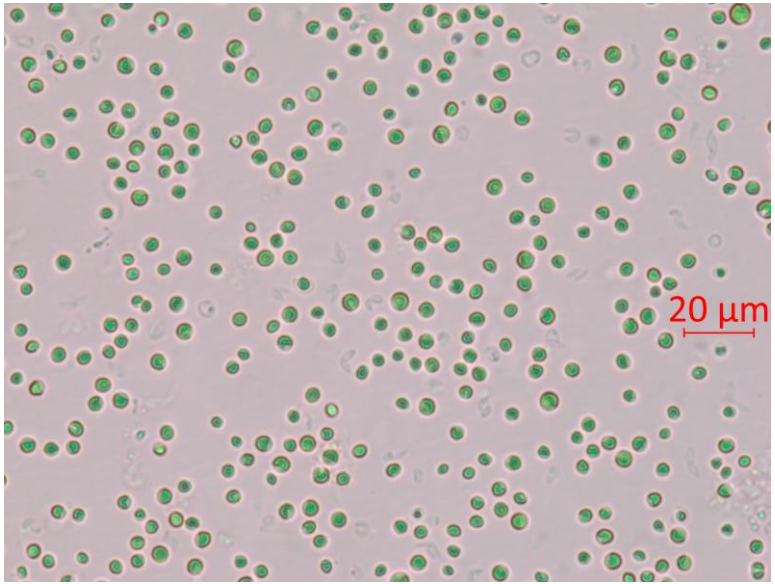
efficient **separation** methods



Microalgal suspension

Microalgae

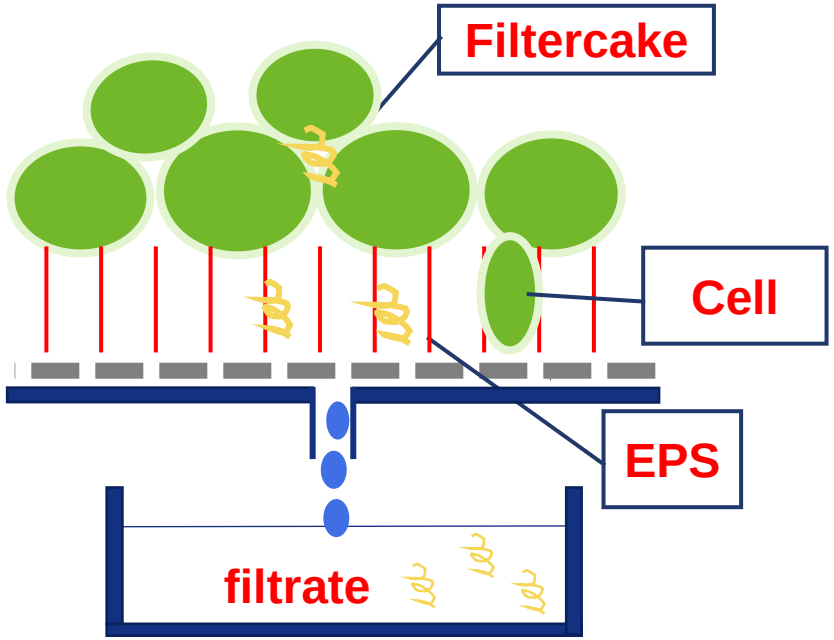
- Low concentration (1 g/L)
- Small (**4.2 µm**)
- Surface charge (-14 mV at pH = 8, salinity 32 g/L)



Nannochloropsis Oculata 40x

Fouling phenomena

- Fouling on/in membrane
  - 1) EPS/cell plug internal pores;
  - 2) Cell block pores' entrance;
  - 3) External filtercake



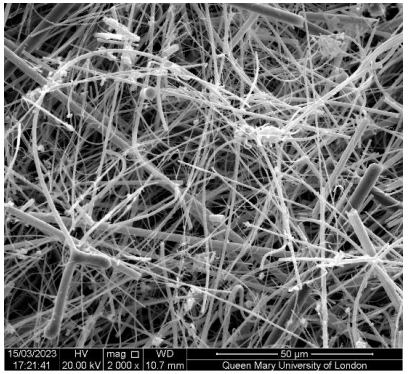
- Aim: understand the fouling from the **decline** in filtrate flow rate across the membrane and cake.

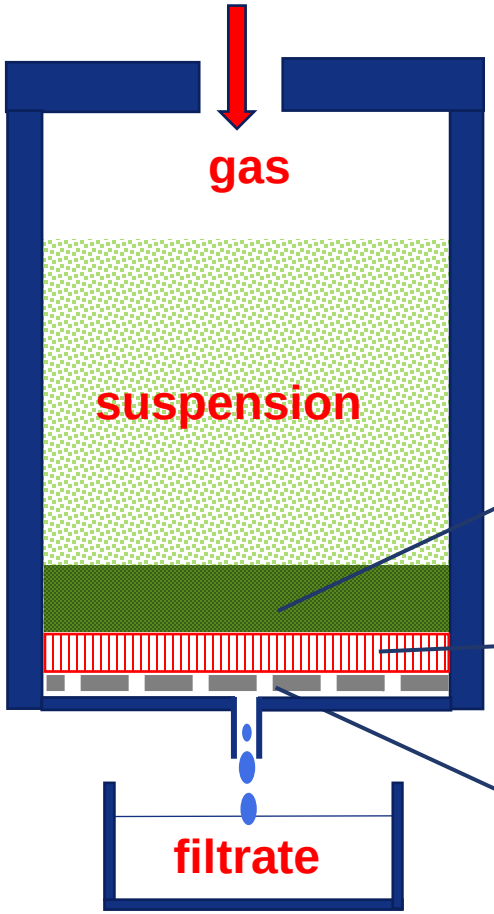
Static filtration process

API filter press

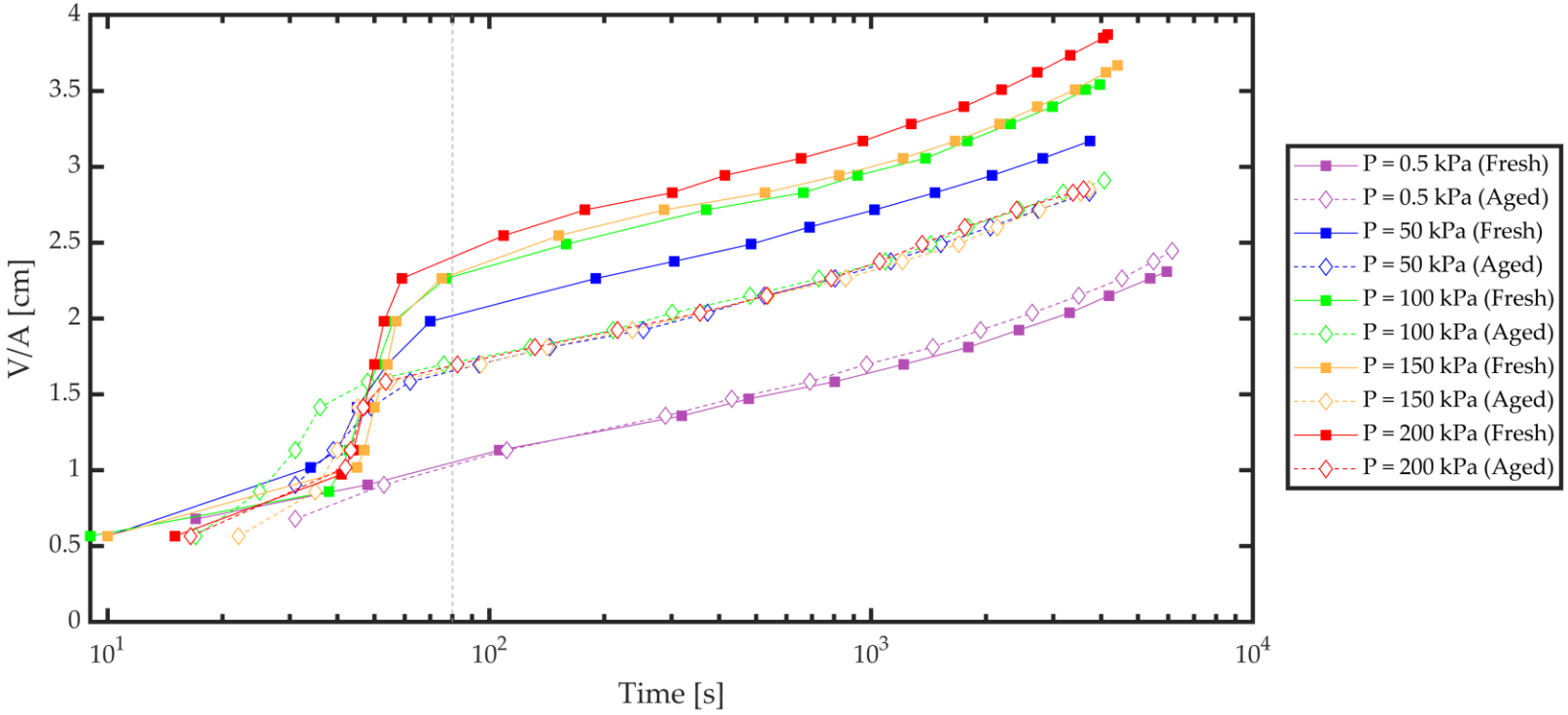
Glass fibre membrane

- Avg.pore size: **1.5** µm
- thickness: **280** µm
- binder-free
- Permeability (**6.42** milliDarcy)





Results- 1: Modelling filtrate flux time-dependence



Results 1: filtrate flux time-dependence

- Based on Darcy's law, a traditional filtration model
- At anytime t, $\boldsymbol{0 < t < T}$

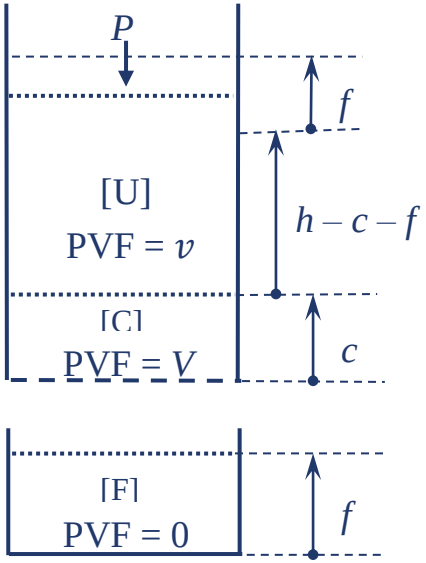
$$\frac{df}{dt} = \frac{Pk}{\eta c}$$

  - $f = V/A$: filtrate volume/area
  - P : pressure
  - k : permeability of filtercake
  - c : filter cake thickness. proportional to filtrate volume, c=**G**f
  - η : suspension viscosity

Results 1: filtrate flux time-dependence

- Based on Darcy's law, a traditional filtration model
- At anytime t, $\boldsymbol{0 < t < T}$

$$\frac{df}{dt} = \frac{Pk}{\eta c}$$



- $f = V/A$: filtrate volume/area
- P : pressure
- k : permeability of filtercake
- η : suspension viscosity
- c : filter cake thickness, proportional to filtrate volume, c=**G**f

Results 1: filtrate flux time-dependence

- Substitute c=**G**f, and Integral from 0 to T

$$f\frac{df}{dt} = \frac{Pk}{\eta G}$$

$$\frac{V}{A} = \left[\frac{2Pk}{\eta G}\right]^{1/2} t^{1/2} \equiv St^{1/2}$$

$$\frac{V}{A} \propto t^{1/2}$$

Root-time behaviour

- ✓ **Valid for rigid particle**
- ✓ **No contamination**
- ✓ **Cake formation**

- *G*: ratio of particle volume fraction
- S: desorptivity of filtercake

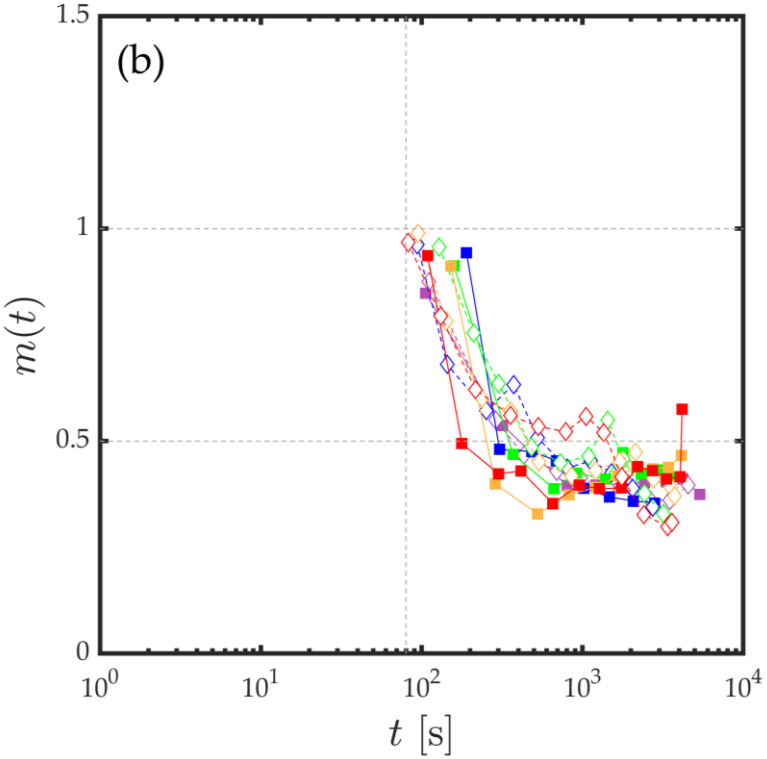
Results 1: filtrate flux time-dependence

In post-spurt phase

$$\frac{(V-V_0)}{A} \propto (t-t_0)^m$$

$$m(t) = \frac{d\,log(V-V_0)}{d\,log(t-t_0)}$$

$$a\ drop! \ \& \ m < 0.5 \quad ???$$

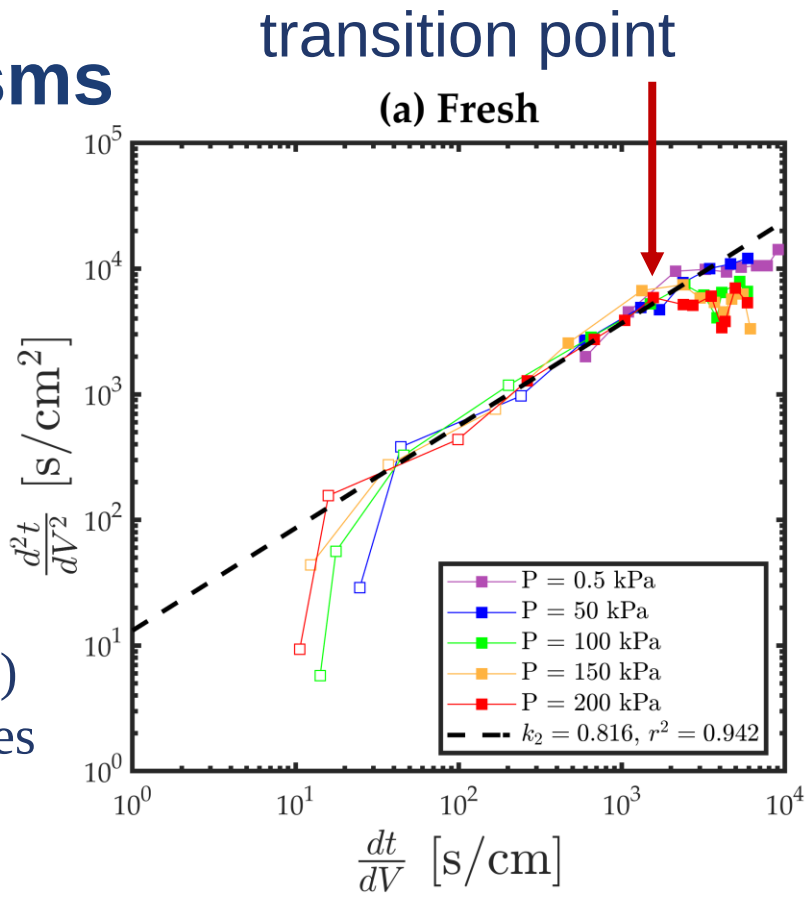


Results 2: Fouling mechanisms

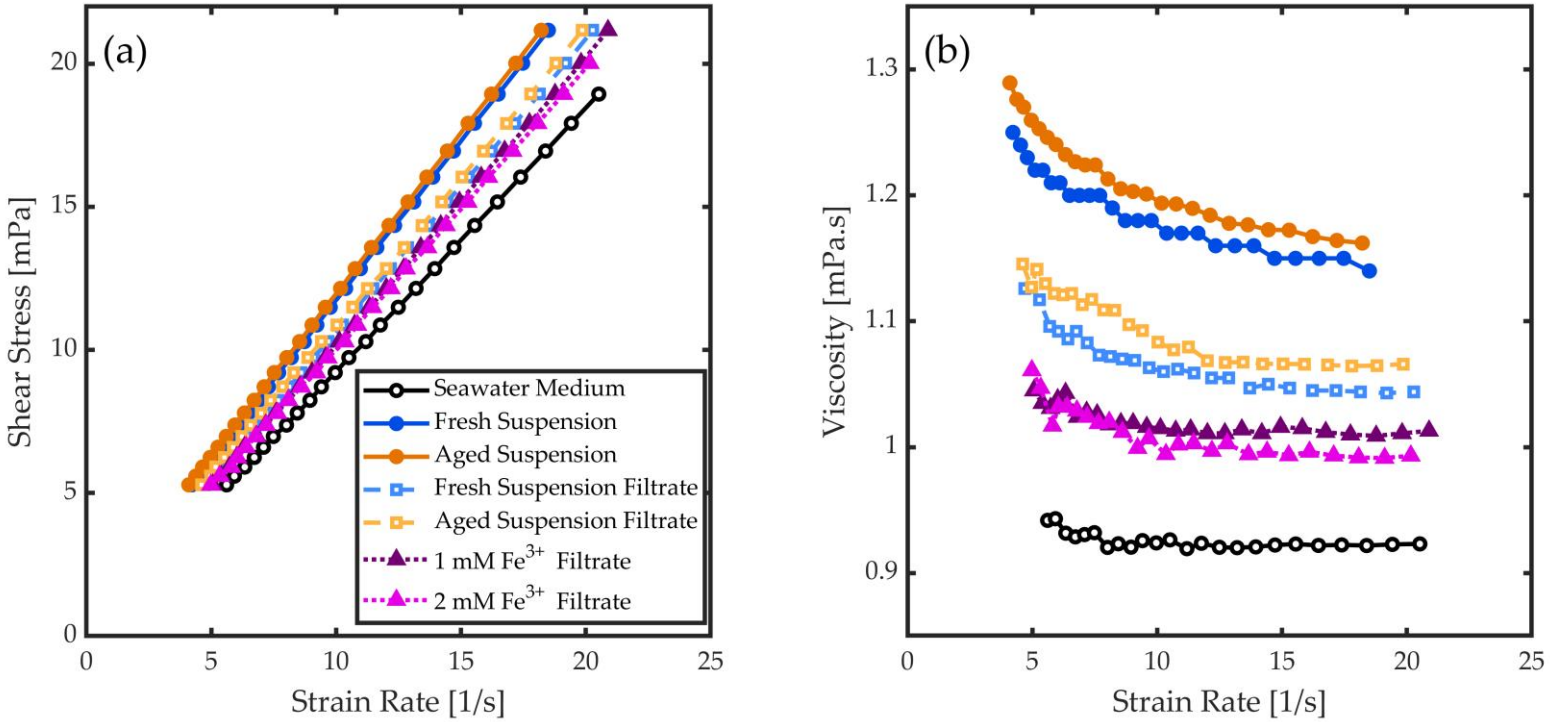
Block filtration model

$$\frac{d^2t}{dV^2} = k_1 \left(\frac{dt}{dV}\right)^{k_2}$$

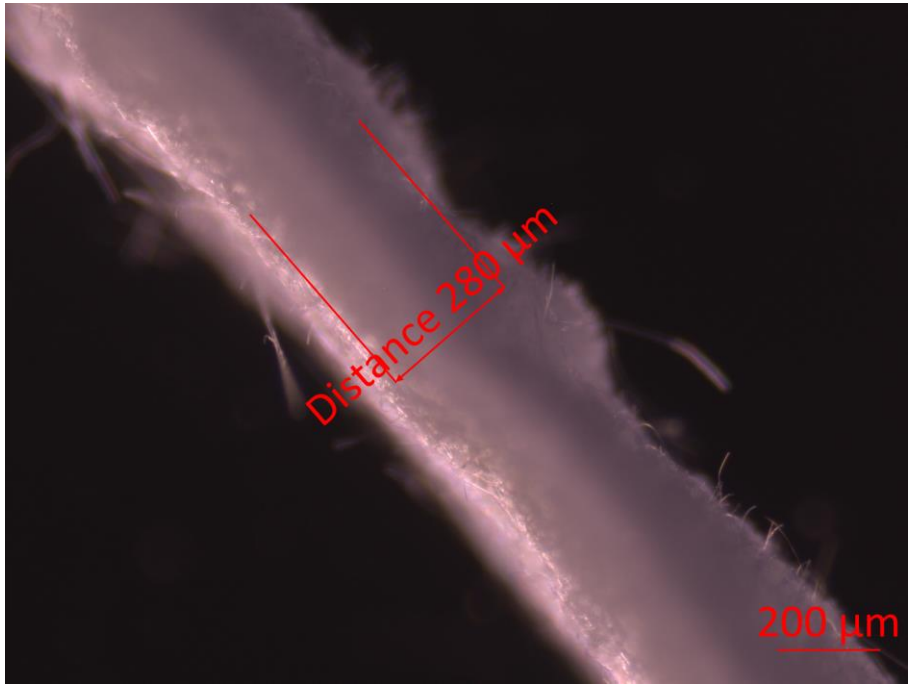
- $k_2 = 0$: Root time
- $k_2 = 1$: Intermediate blocking (pore entrances)
- $k_2 = 1.5$: Standard blocking (the small particles are deposit within the filter)
- $k_2 = 2$: Complete block

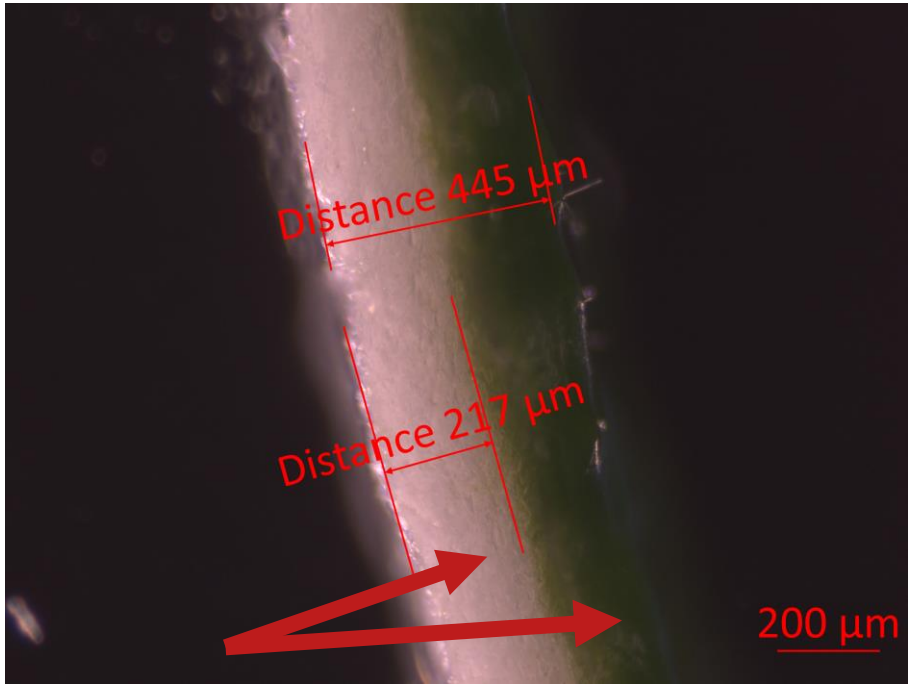


Results 3: Flux decline by EPS?



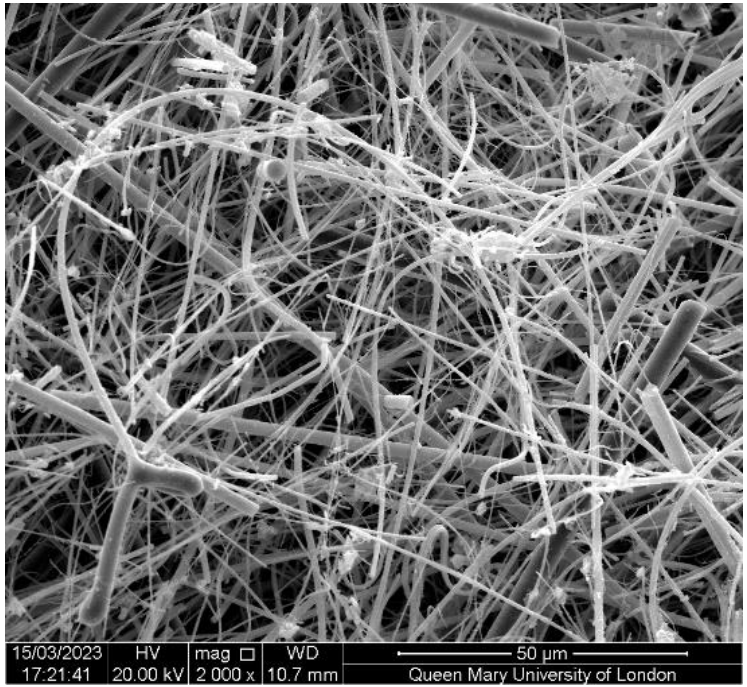
Result-3: Cell invasion

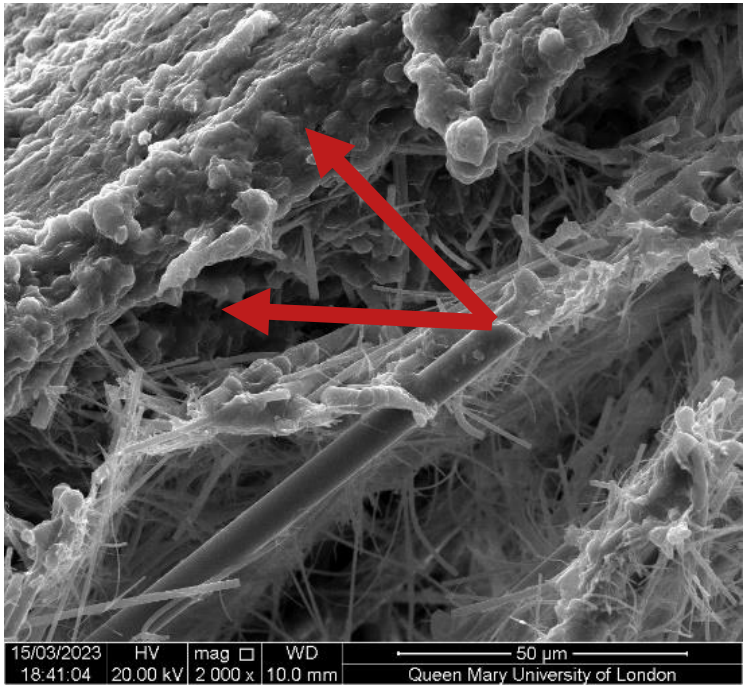




Before filtration and after filtration (50 kPa)

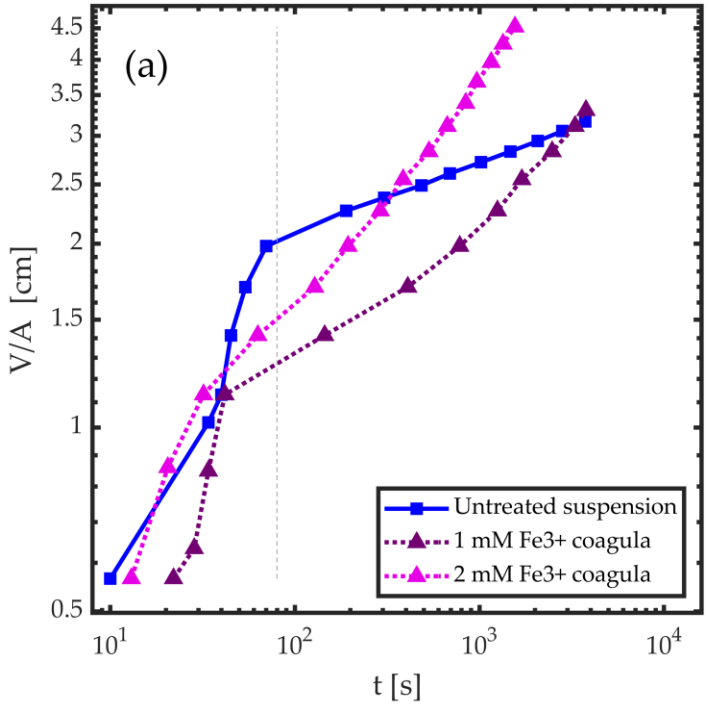
Result-3: Cell invasion - pore blocking

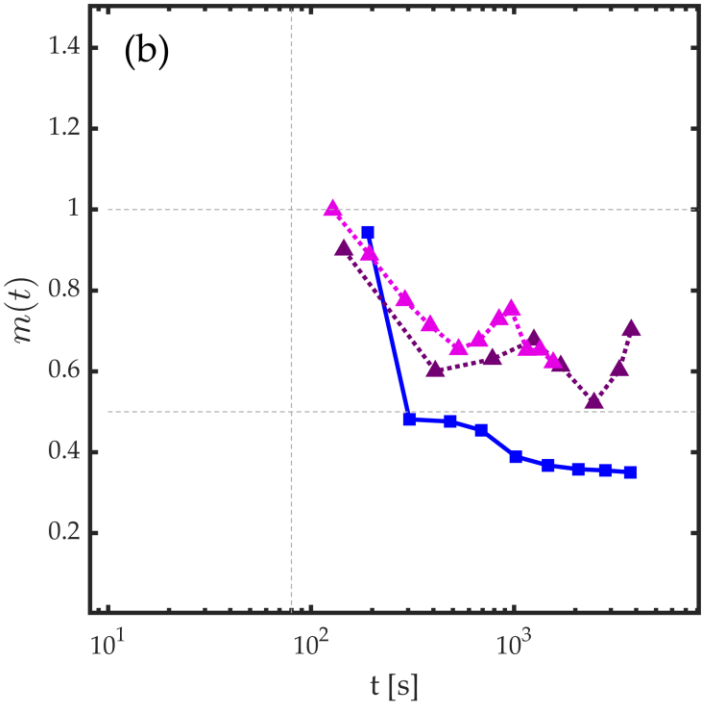




Before filtration and after filtration (50 kPa)

Future solution: stop cell invasion into membrane!





Results – Summary

- A time-dependent relation.
- Invasion of membrane by cells.
- Pore blocking mitigation.

Future study:

- ➢ Compressibility of cake layers
- ➢ Dynamic filtration of algal flocs

Acknowledgement

Many thanks to **QMUL-CSC** for fully funding my PhD research, I appreciate the **Queen Mary Postgraduate Research Fund** for supporting my travel. I also appreciate my industrial supervisor, **Dr Gerald Meeten**, **Dr Tim G.J. Jones**, for providing generous guidance after retiring since 2020.

Results can be found here: Membrane Fouling During the Harvesting of Microalgae Using Static Microfiltration. SPT, https://doi.org/10.1016/j.seppur.2024.127737

Thank you