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Heterogeneous biofilms can help to stabilize long-term flux in gravity-driven ultra-low pressure ultrafiltration systems

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Context

900 M people using unprotected water sources *(Data: MDG 2008)*

500 million people: health problems due to the lack of safe drinking water

5.3 billion people (83%) → recontamination of water
(Data: WHO, HWTS Network, 2006)

Solution

Decentralized membrane systems→ reduced risk of water related diseases
(*Montgomery, M.A., Elimelech, M Environ. Sci. Technol. 41, 17-24 (2007).*

Effective, low-cost, robust and less chemical- and energy- intensive than other technologies
Shannon M.A. et al. Nature 452, 301-310 (2008).

Gravity-driven ultra-low pressure ultrafiltration system

No energy requirement

No backwashing

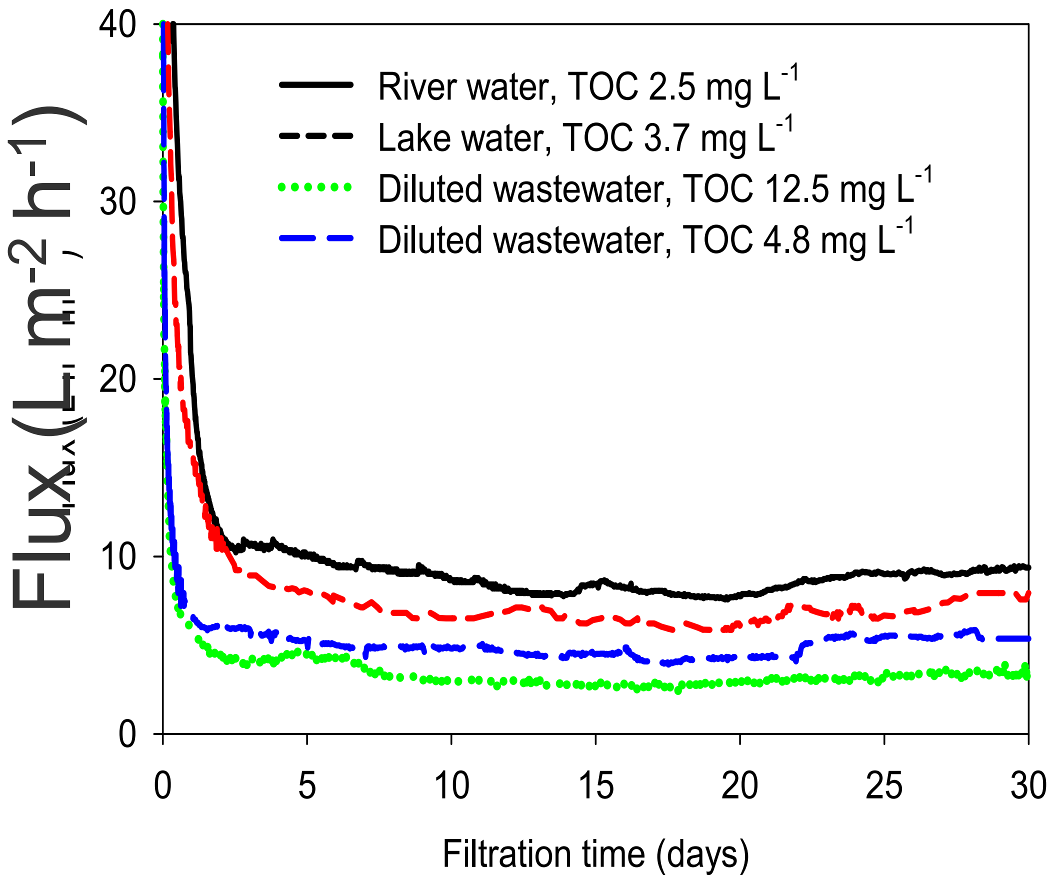
No cleaning

No cross-flow

Picture from Butler R., 2009

Hydrostatic pressure 65mBar

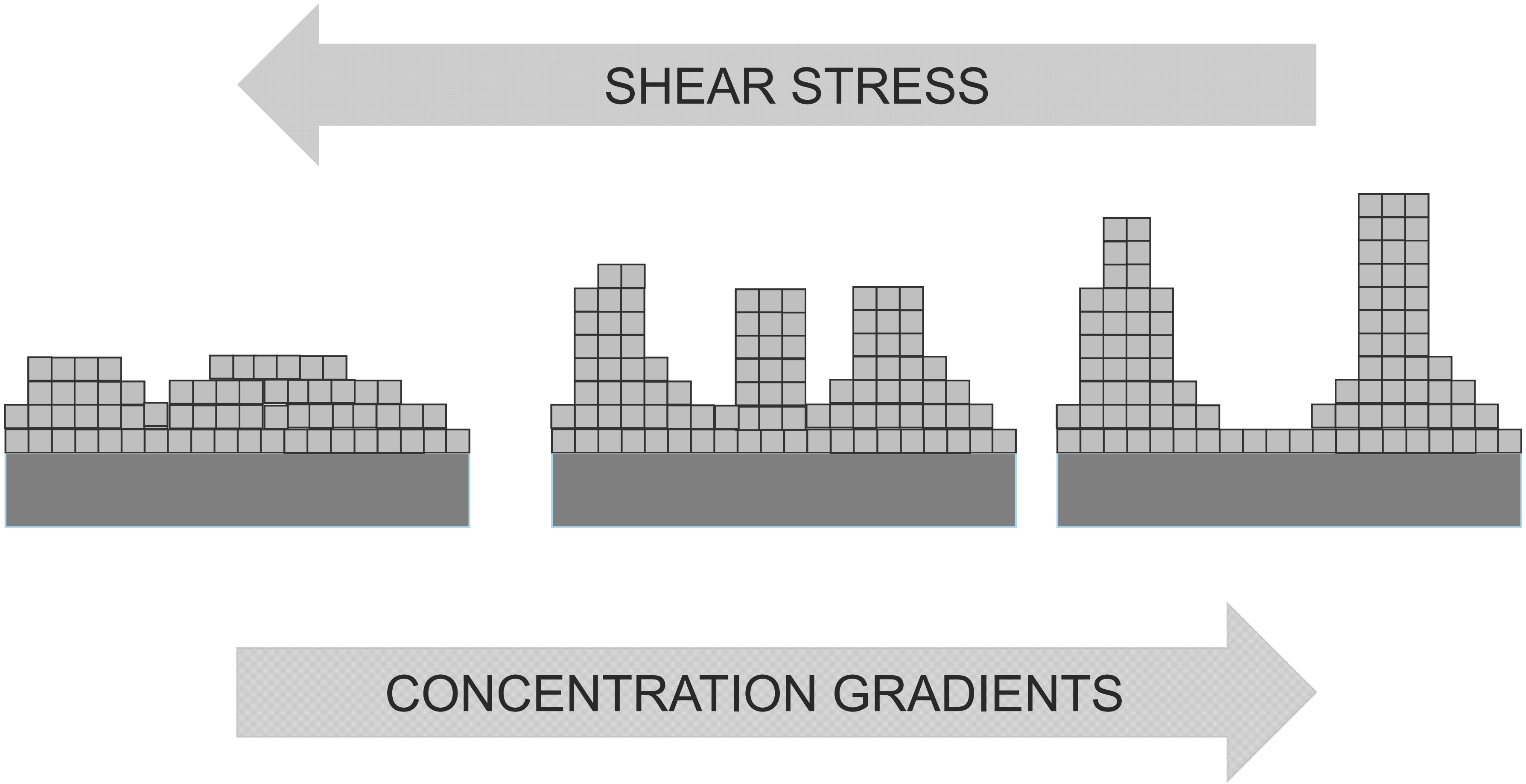
Gravity-driven ultra-low pressure ultrafiltration



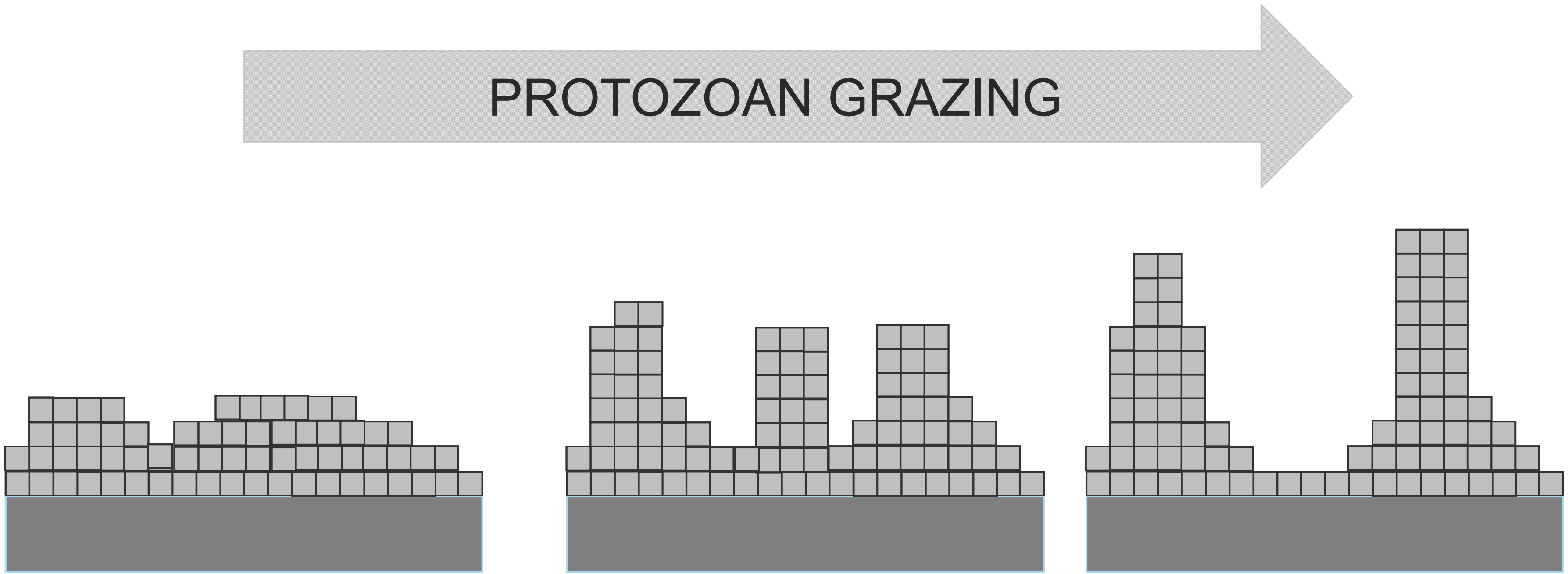
Flux stabilization due to the bacterial activity in the BFL

What is the process governing the development of different BFL structure?

Peter-Varbanet et al. (2010). Water Research 43 (2).


SHEAR STRESS
CONCENTRATION GRADIENTS

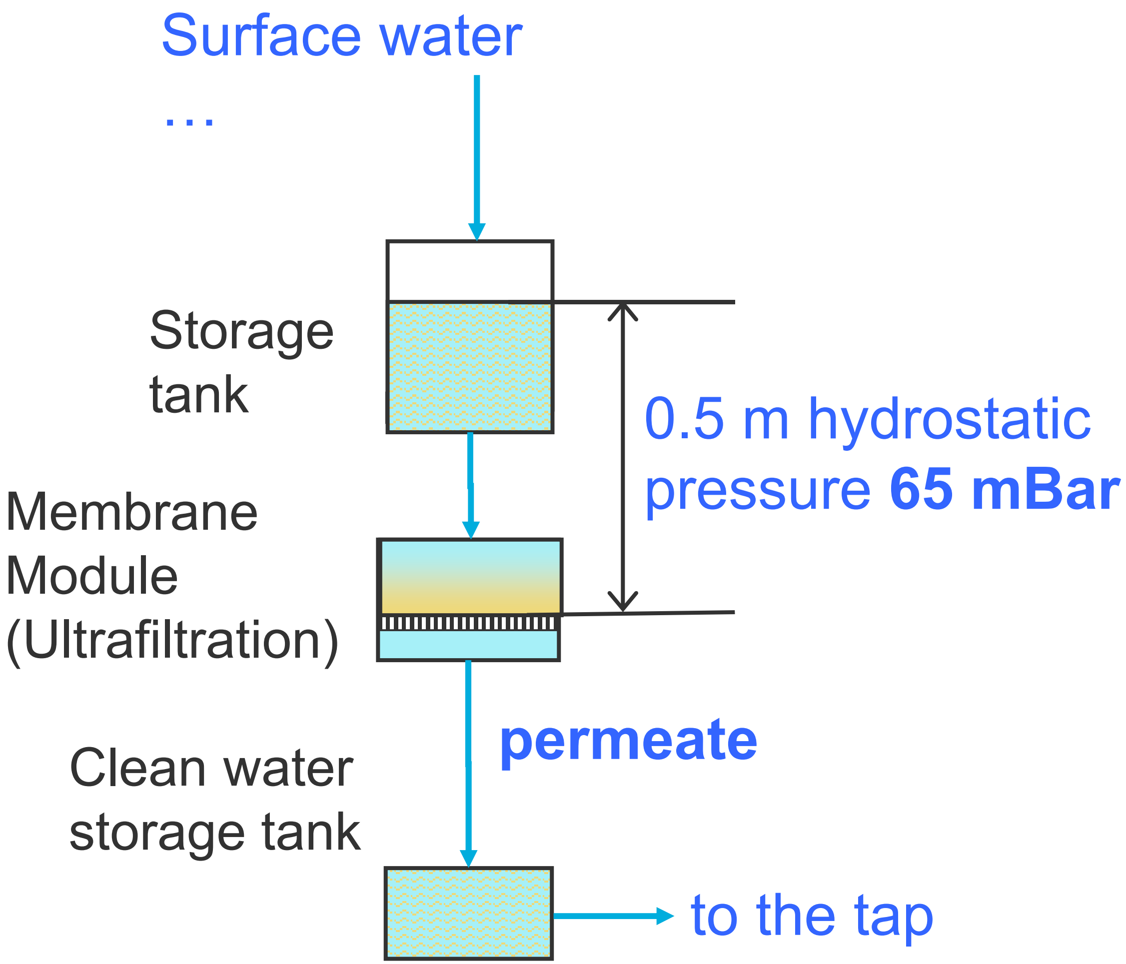
Objectives of this study



#1: How does protozoan grazing influence the biofouling layer structure?

#2: How does the development of an open structure help to maintain high flux?

Experimental Approach



Low-PG: inhibition using cycloheximide

Nat.-PG: no control

High-PG: inoculation of the system using *Tetrahymena Pyriformis*

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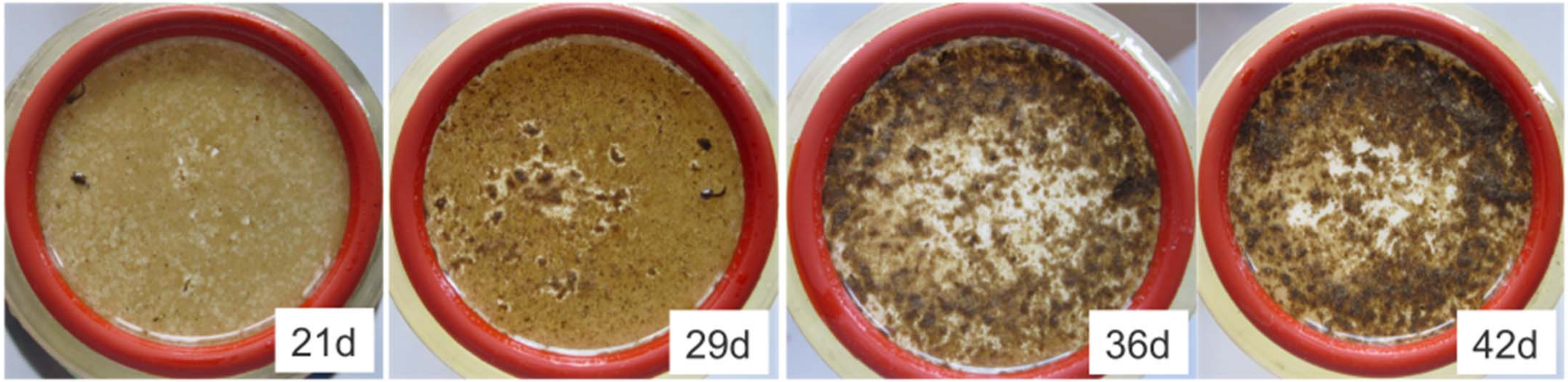

Dynamic structure of the biofouling layer “Nat.-PG”

Homogeneous, flat basal layer → open and heterogeneous

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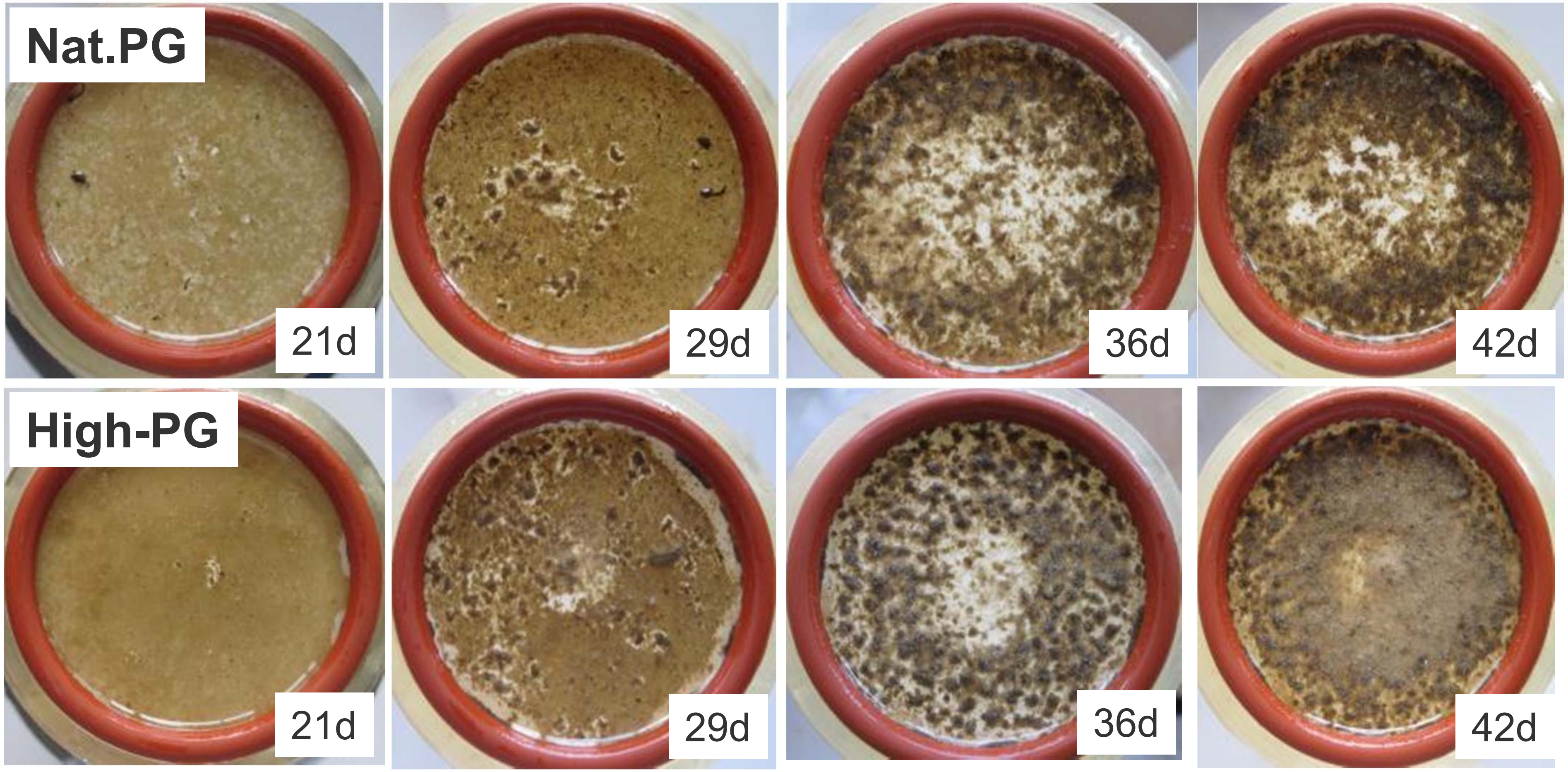

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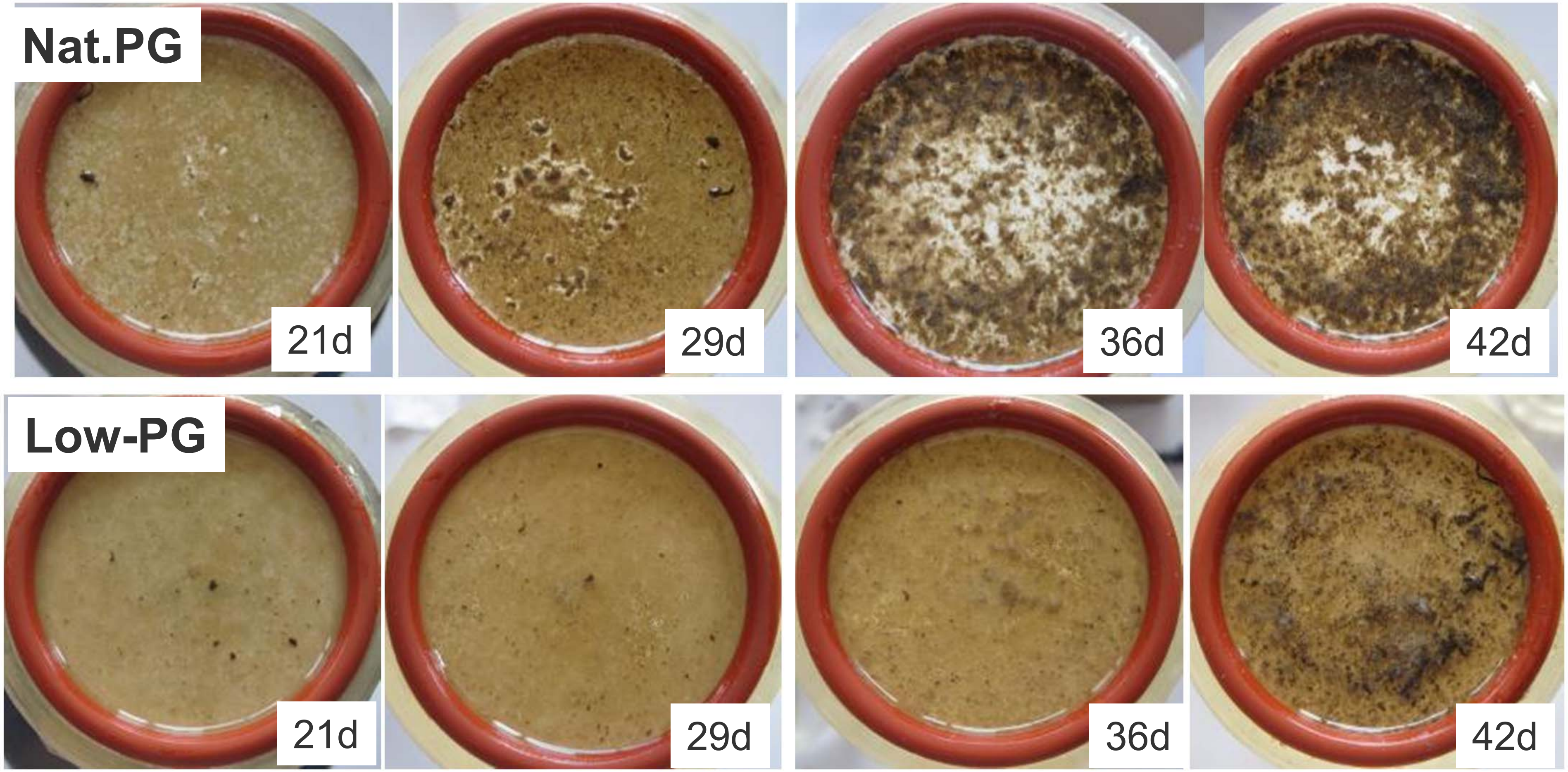

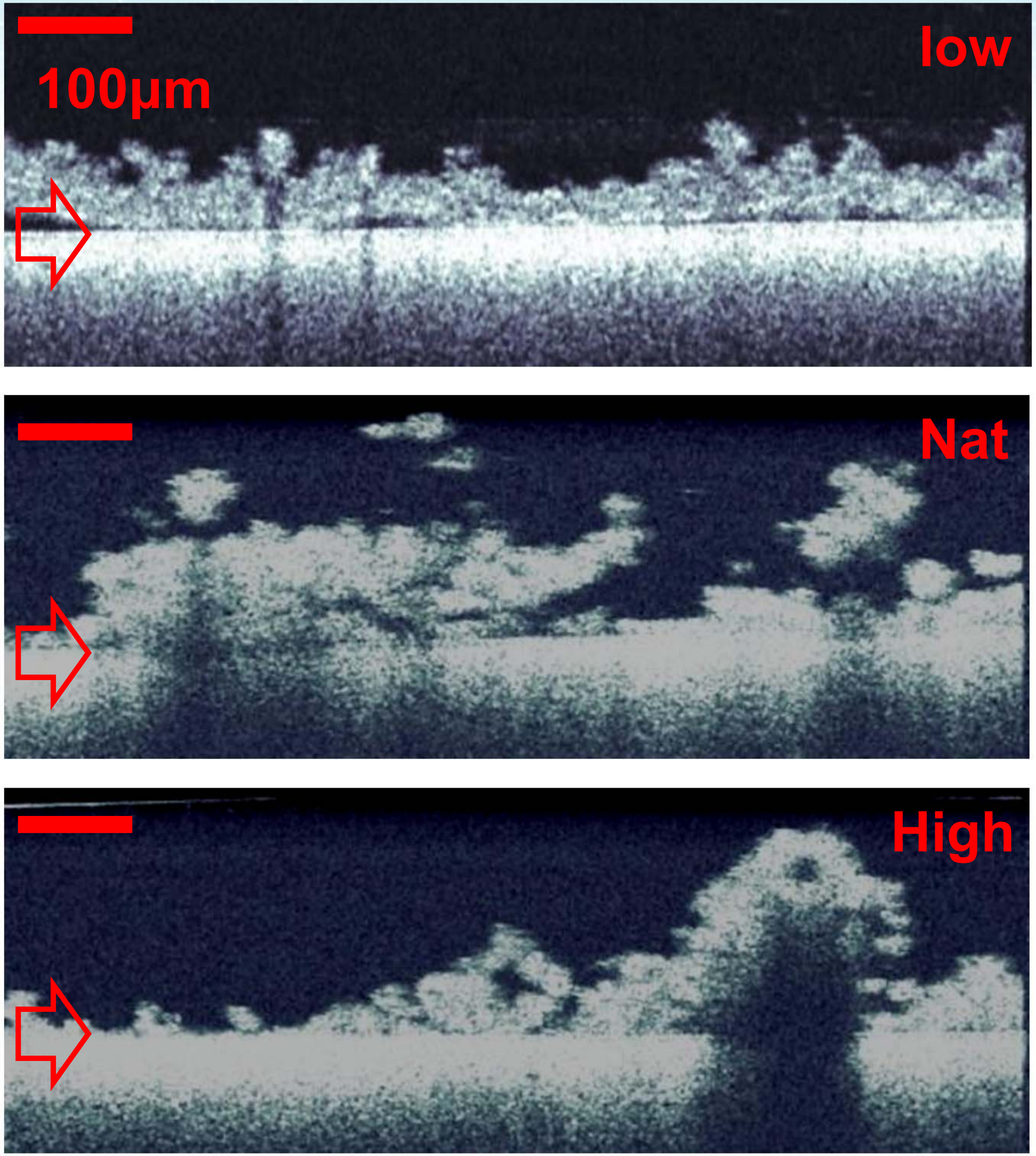

Optical Coherence Tomography

Protozoan grazing favors the growth in z-direction at the meso-scale

OCT images without treatment

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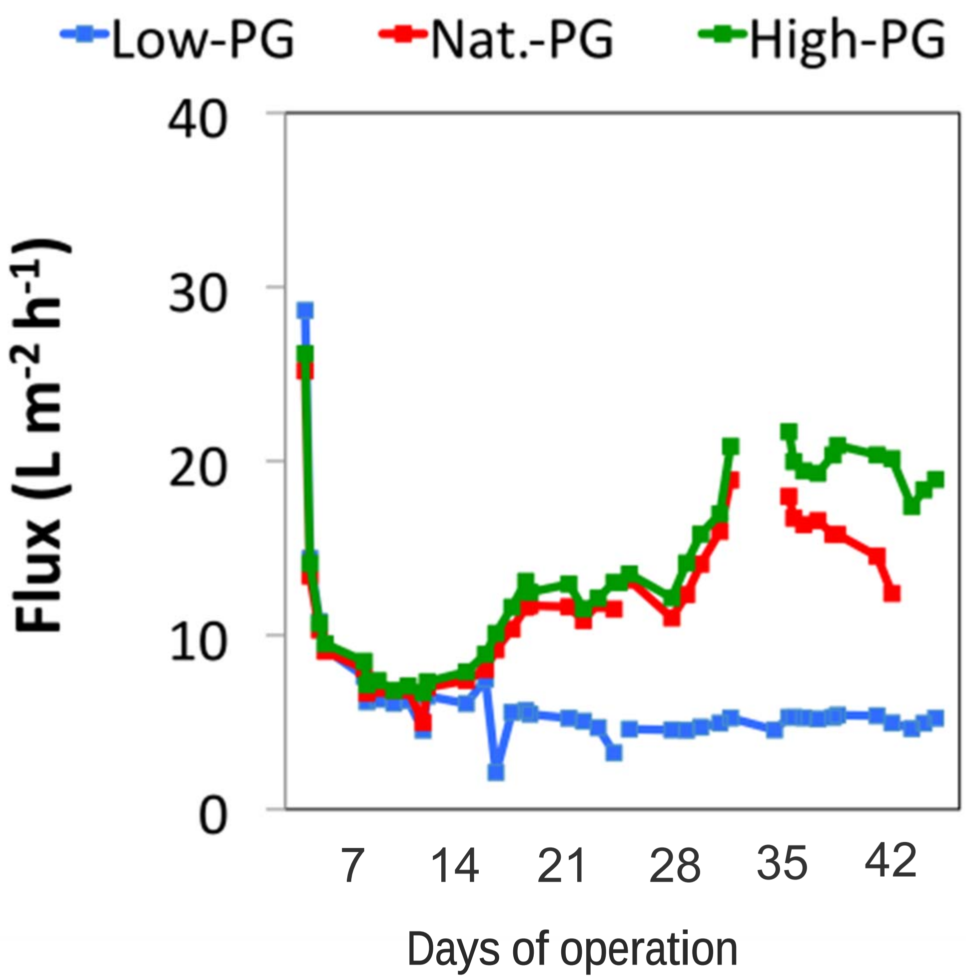

No membrane biofouling

Dynamic flux evolution with protozoa

Stable flux without grazing

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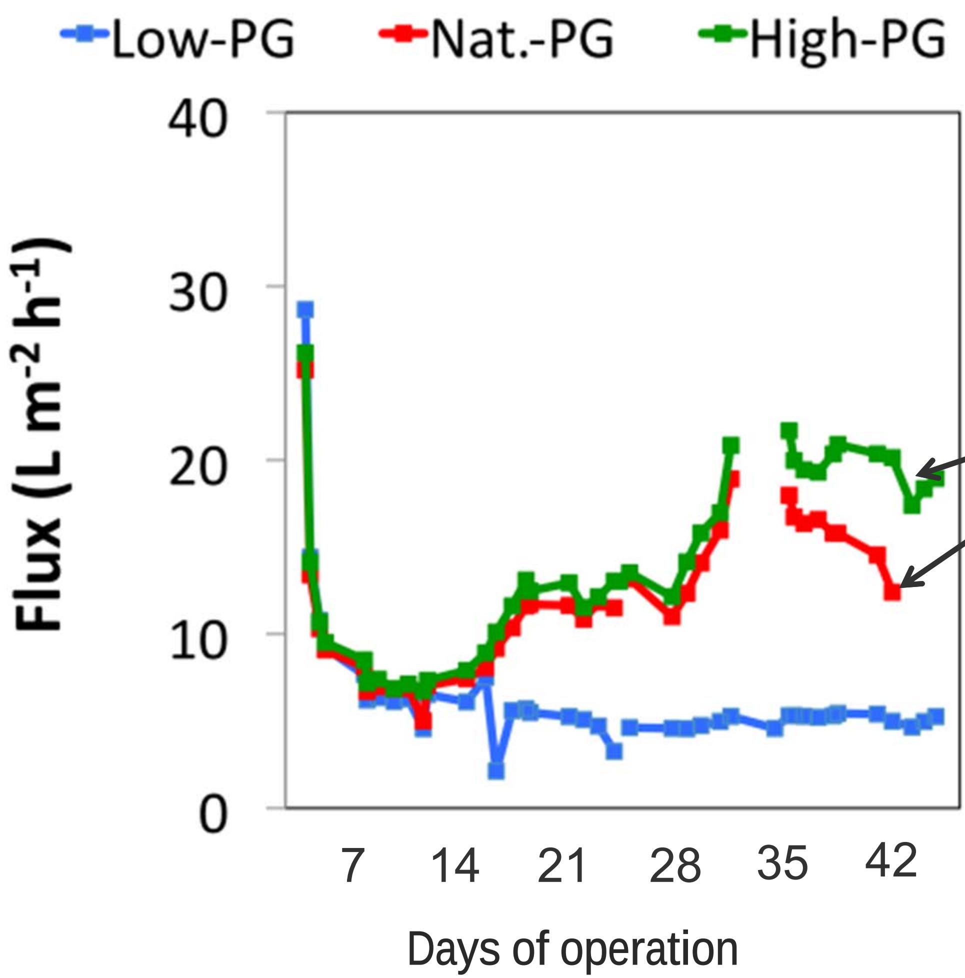

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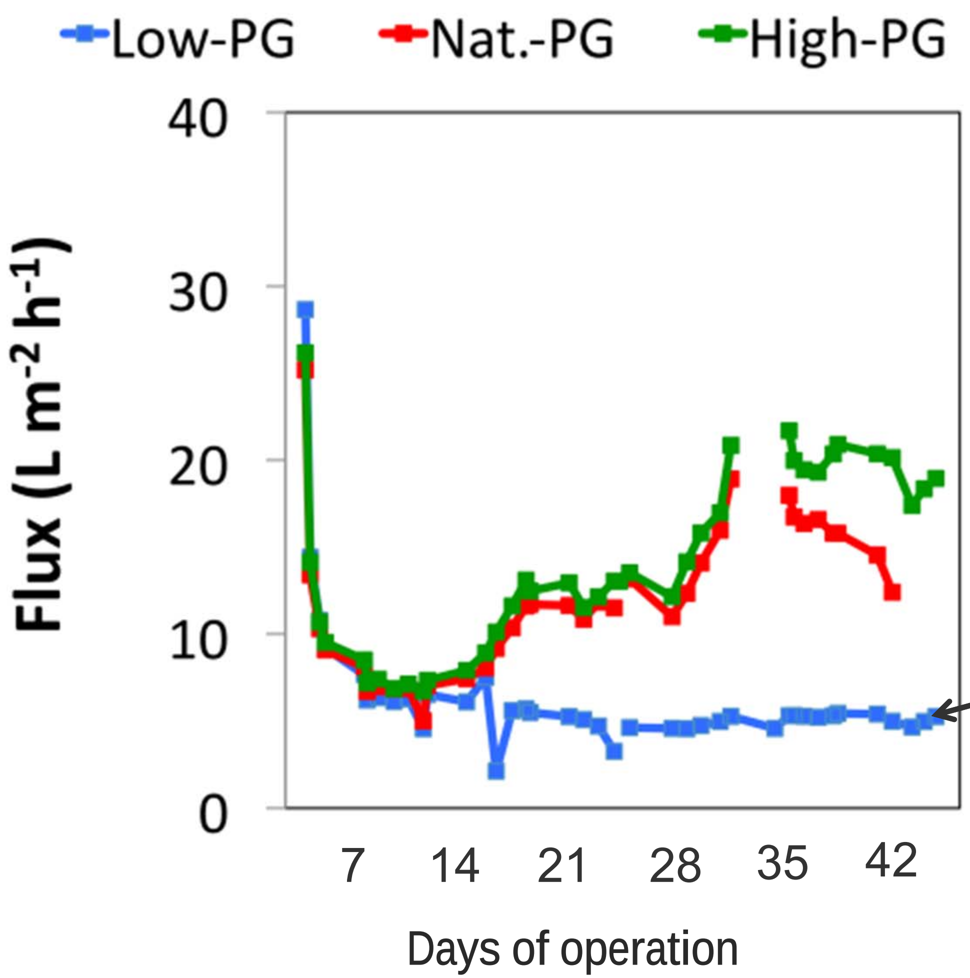

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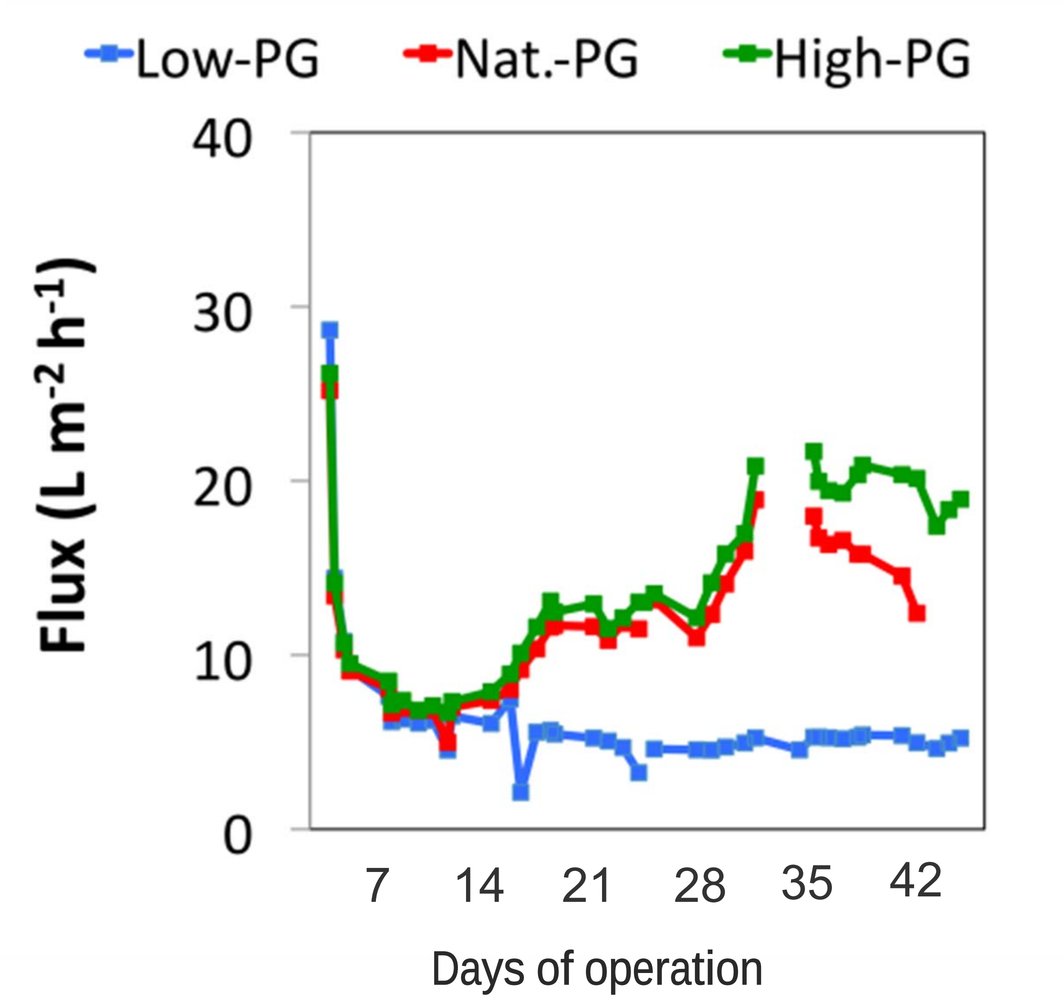
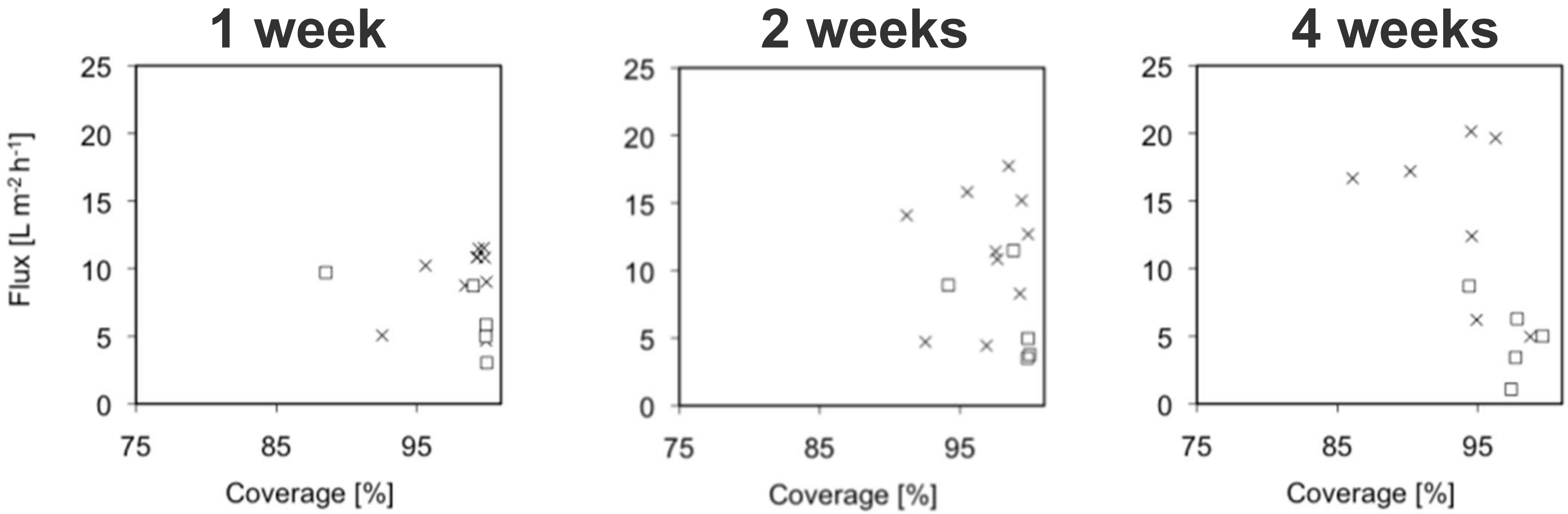


How are structural heterogeneities and system performances linked?



× with protozoan grazing ☐ without protozoan grazing

Image analysis to measure the "uncovered" membrane fraction (ImageJ : http://rsbweb.nih.gov/ij/)

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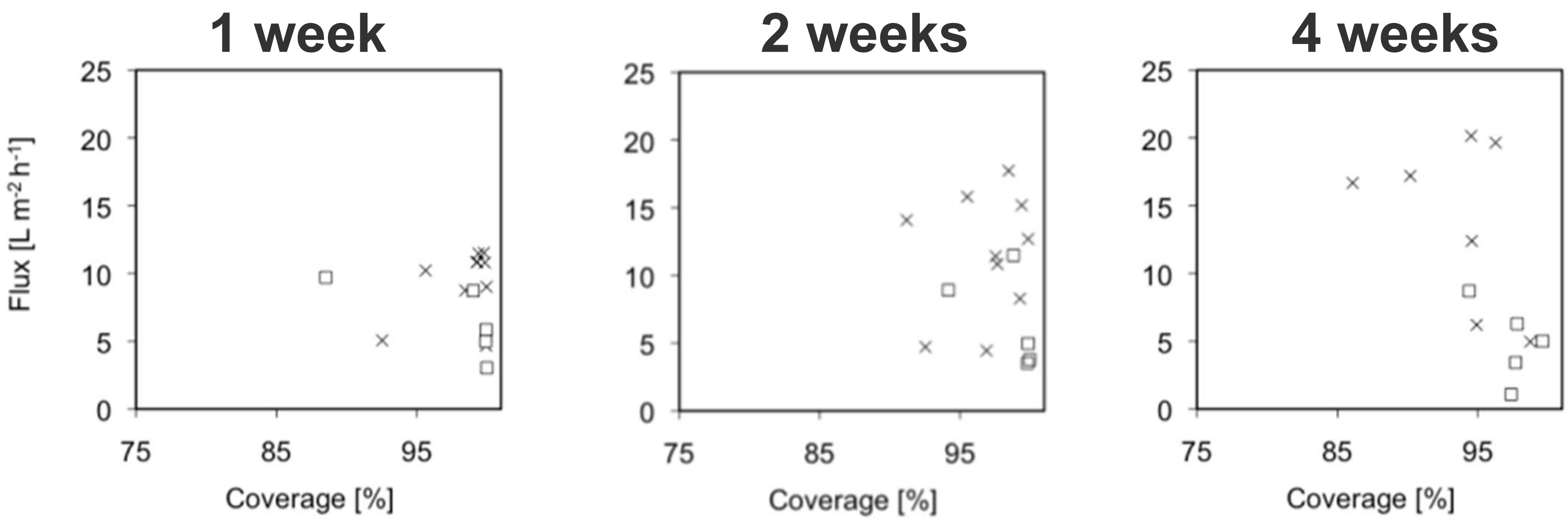

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Small variation of coverage induces a significant increase of the flux, why?

Membrane coverage – after one month

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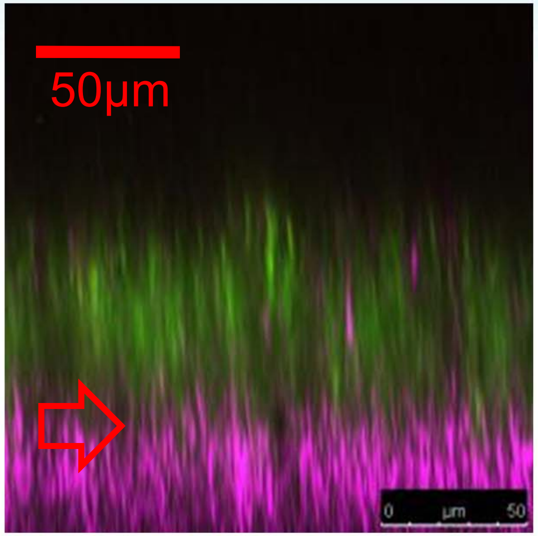
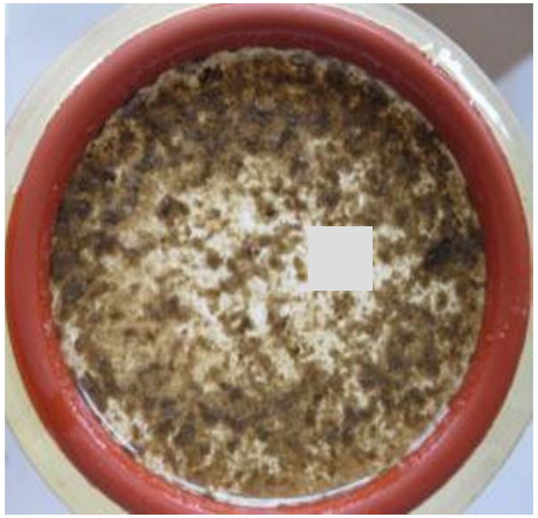
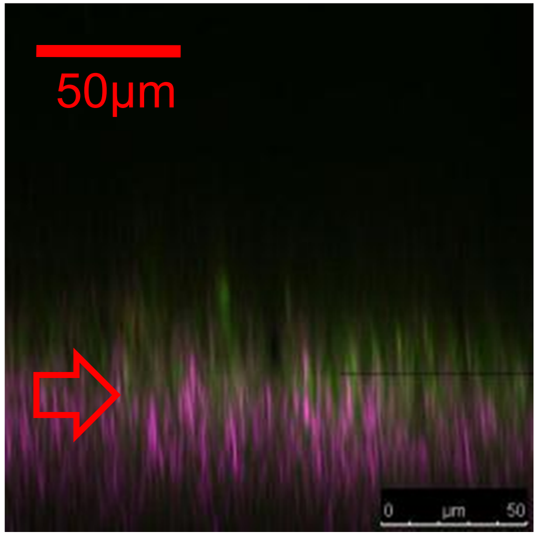
Low PG



Nat. PG





- All bacterial cells (SYBR® Gold) - Particles and the membrane (Reflection)

Membrane coverage – after one month

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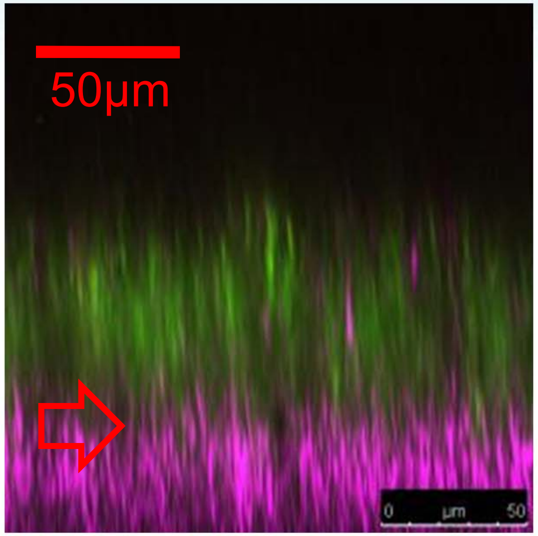

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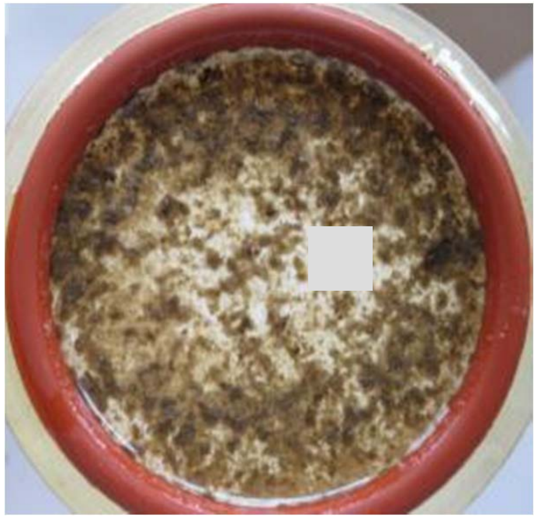
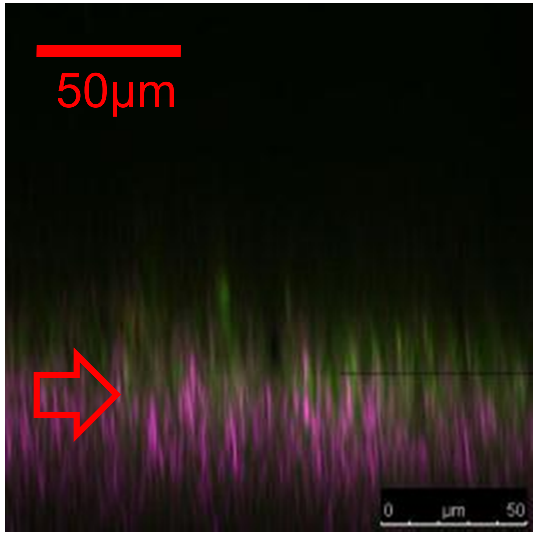
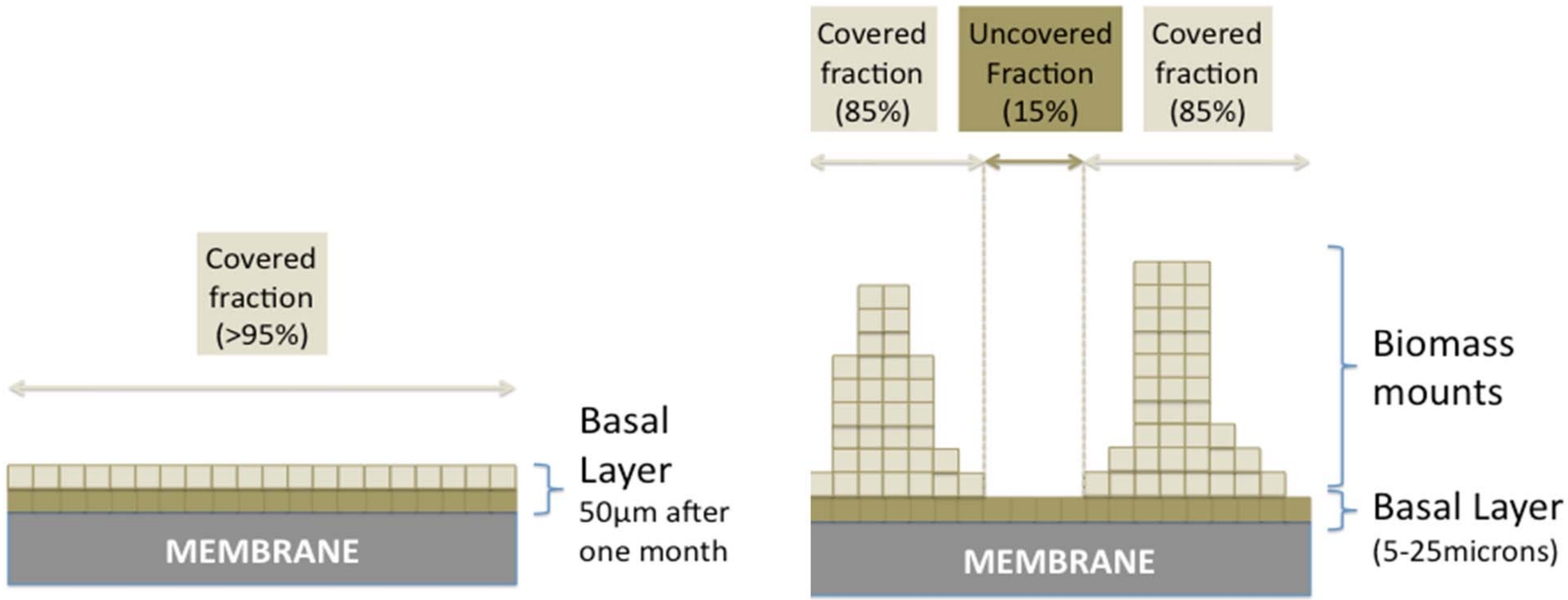




Thinner local thickness induces smaller local hydraulic resistance

Conclusions and perspectives

Protozoan shapes the BFLstructure. The change in the filtration performances is explained by the reduction of the surface coverage associated with a thinner basal layer



System is suitable to provide drinking/cooking water: 60 - 15 people per day with 1 m^2 of membrane considering 2-8 L/person/day for drinking/cooking

System is stable: stable flux observed over 1.5 year

Significant impact of protozoan grazing is more and more observed

- Biofilm structure *(Böhme et al., 2009; Garny et al., 2009)*
- Granulation *(Weber et al., 2007)*
- Reactor stability *(Aspergen et al., 2010; Duque and Morgenroth, submitted)*
- Pathogen removal *(Bomo et al., 2009)*

Thanks for your attention