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 \((Data: \text{MDG 2008})\)

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

5.3 billion people \((83\%)\) \(\rightarrow\) recontamination of water
\((Data: \text{WHO, HWTS Network, 2006})\)

Solution

Decentralized membrane systems \(\rightarrow\) reduced risk of water related diseases

Effective, low-cost, robust and less chemical- and energy- intensive
than other technologies
\(Shannon M.A. \text{ et al. Nature 452, 301-310 (2008).}\)
Gravity-driven ultra-low pressure ultrafiltration system

- No energy requirement
- No backwashing
- No cleaning
- No cross-flow

Picture from Butler R., 2009
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?

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

Surface water

Storage tank

Membrane Module (Ultrafiltration)

Clean water storage tank

permeate

to the tap

0.5 m hydrostatic pressure 65 mBar

Low-PG: inhibition using cycloheximide

Nat.-PG: no control

High-PG: inoculation of the system using Tetrahymena Pyriformis
#1: How does protozoan grazing influence the biofouling layer structure?
#1: How does protozoan grazing influence the biofouling layer structure at the mesoscale?

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

Homogeneous, flat basal layer → open and heterogeneous
#1: How does protozoan grazing influence the biofouling layer structure at the mesoscale?
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Protozoan grazing favors the growth in z-direction at the meso-scale.

Optical Coherence Tomography

OCT images without treatment
#2 How does the development of an open structure help to maintain high flux?
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- No membrane biofouling
- Dynamic flux evolution with protozoa
- Stable flux without grazing
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<table>
<thead>
<tr>
<th>Days of operation</th>
<th>Low-PG</th>
<th>Nat.-PG</th>
<th>High-PG</th>
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- **No membrane biofouling**
- **Dynamic flux evolution with protozoa**
- **Stable flux without grazing**
#2: How does the development of an open structure help to maintain high flux?
How are structural heterogeneities and system performances linked?

1 week

2 weeks

4 weeks

× with protozoan grazing
☐ without protozoan grazing

Image analysis to measure the “uncovered” membrane fraction (ImageJ: http://rsbweb.nih.gov/ij/)
How are structural heterogeneities and system performances linked?

Small variation of coverage induces a significant increase of the flux, why?
Membrane coverage – after one month

Low PG

Nat. PG

- All bacterial cells (SYBR® Gold)  - Particles and the membrane (Reflection)
Membrane coverage – after one month

Low PG

Nat. PG

50μm

50μm

Thinner local thickness induces smaller local hydraulic resistance
Conclusions and perspectives
Protozoan shapes the BFL structure. 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 m² 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