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Looking inside slow sand filters from fundamental scale to application scale

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Introduction

✓ Understanding subsurface transport of colloids such as pathogenic microorganisms is important to prevent waterborne diseases.

✓ The biofilm on top of slow sand filters (The Schmutzdecke) can affect colloids transport by altering media surface properties, porosity and permeability.

✓ A multi scale study is crucial to investigate the role of biofilm on removal and attachment mechanisms inside slow sand filters (SSF).

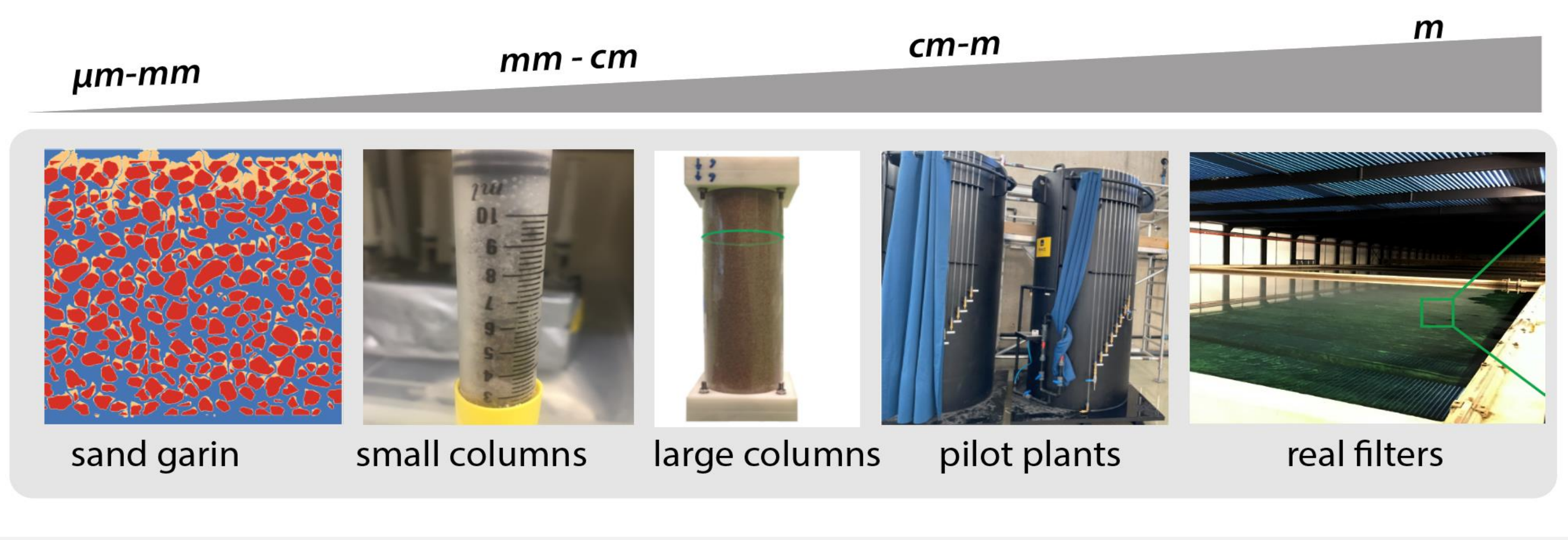

Figure 1: **Investigation of colloids removal in slow sand filters at different scales**

Aim

✓ revealing links between schmutzdecke characteristics and filtration performance

Method

After 75 days of running the filters:

✓ Taking Schmutzdecke samples from different filters to measure biomass, carbohydrate, and protein content

✓ Spiking High titer *E.coli* WR1 bacteria into the filters

✓ Taking water samples at influent, and effluent of the filters to measure bacterial removal efficiency.

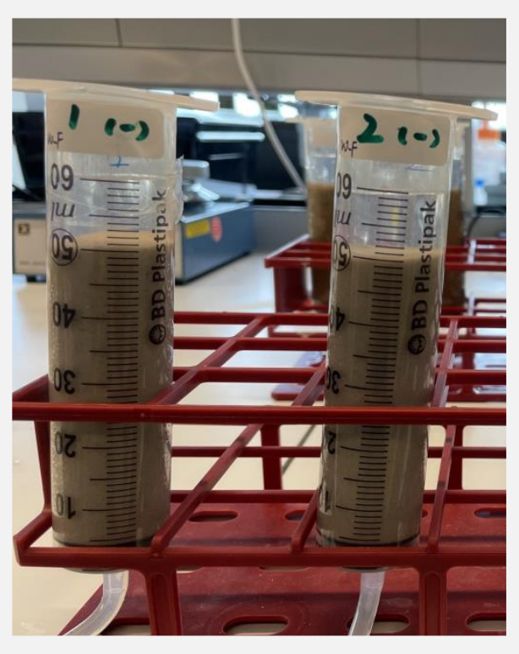

Figure 2: **Syringe scale Filters (UvA)**

Correlation equation

$$\log_{10}\left(\frac{C}{C_0}\right) = -0.22 + 1.90*(\text{Protein/Carbohydrate}) + 0.34*\text{SD\_inoc}\begin{cases}\text{Yes=1}\\ \text{No=0}\end{cases}$$

Results

✓ Virgin fine sand was the most effective sand in bacterial removal.

✓ Inoculated filters showed higher efficiency than non-inoculated ones.

✓ (Protein/Carb) ratio was the only significant parameter in predicting log10 removal values.

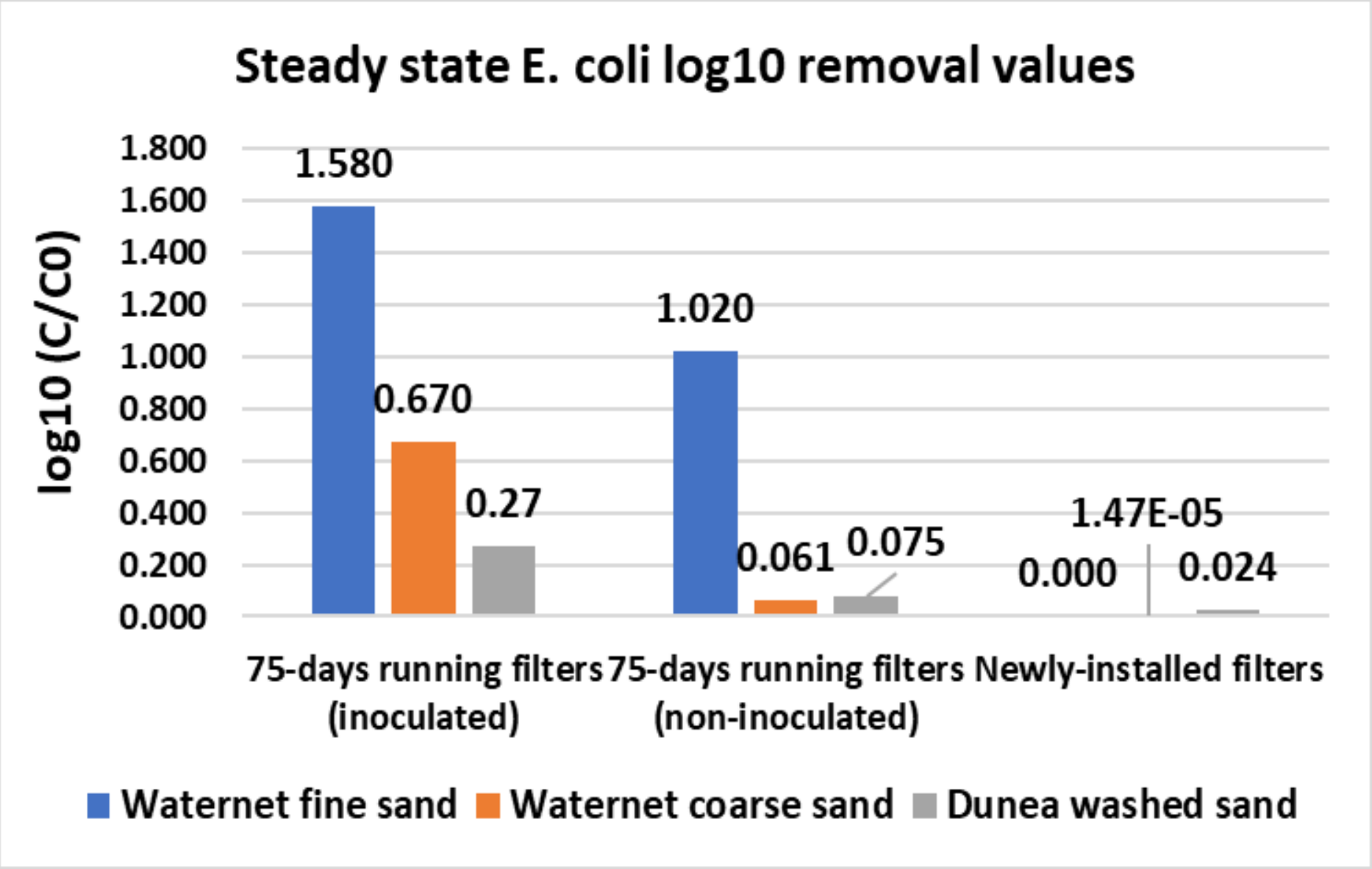

Figure 3: **Various filters *E.coli* log10 removal values**

Micro scale experiments: Sand filters on chip

Advantages of using microfluidics

❑ Direct observation of colloids and biomass interactions, biomass development and morphology

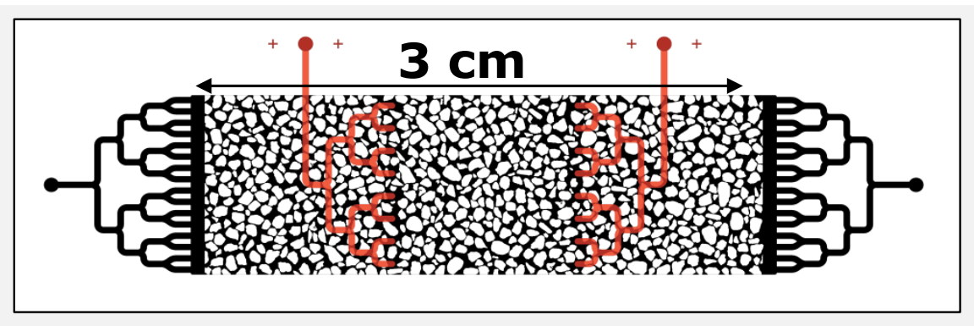

Figure 4: **microfluidic devices**

❑ Gaining insight into pore-scale processes and attachment mechanisms

Methods

❑ Developing biofilms of different ages inside microfluidics

❑ Spiking 1.5 µm green fluorescent colloids into the models to measure colloids removal efficiency

❑ Utilizing fluorescent imaging coupled with image analysis to track colloids within the models

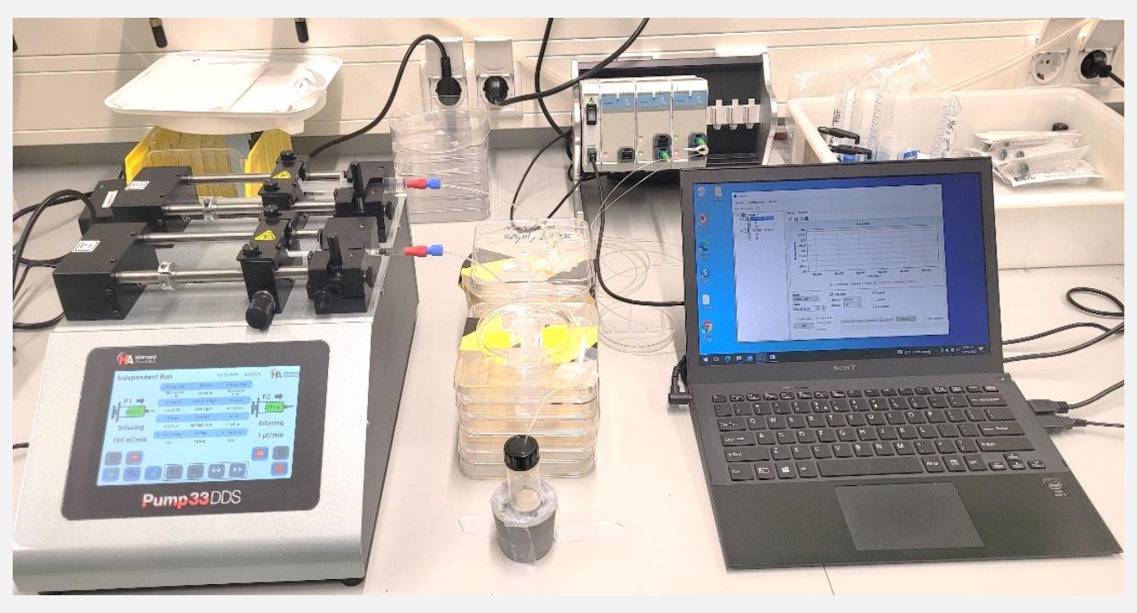

Figure 5: **Setup of biofilm growth**

❑ Staining biofilm and observing morphology under confocal microscopy

Results

BTCs

❑ Log removal efficiency of 1.5 µm colloids increased from 0.18 under clean condition to 0.24, 0.56, and 1.9 under 1-day, 2.5-day, and 7-day biofilm conditions, respectively.

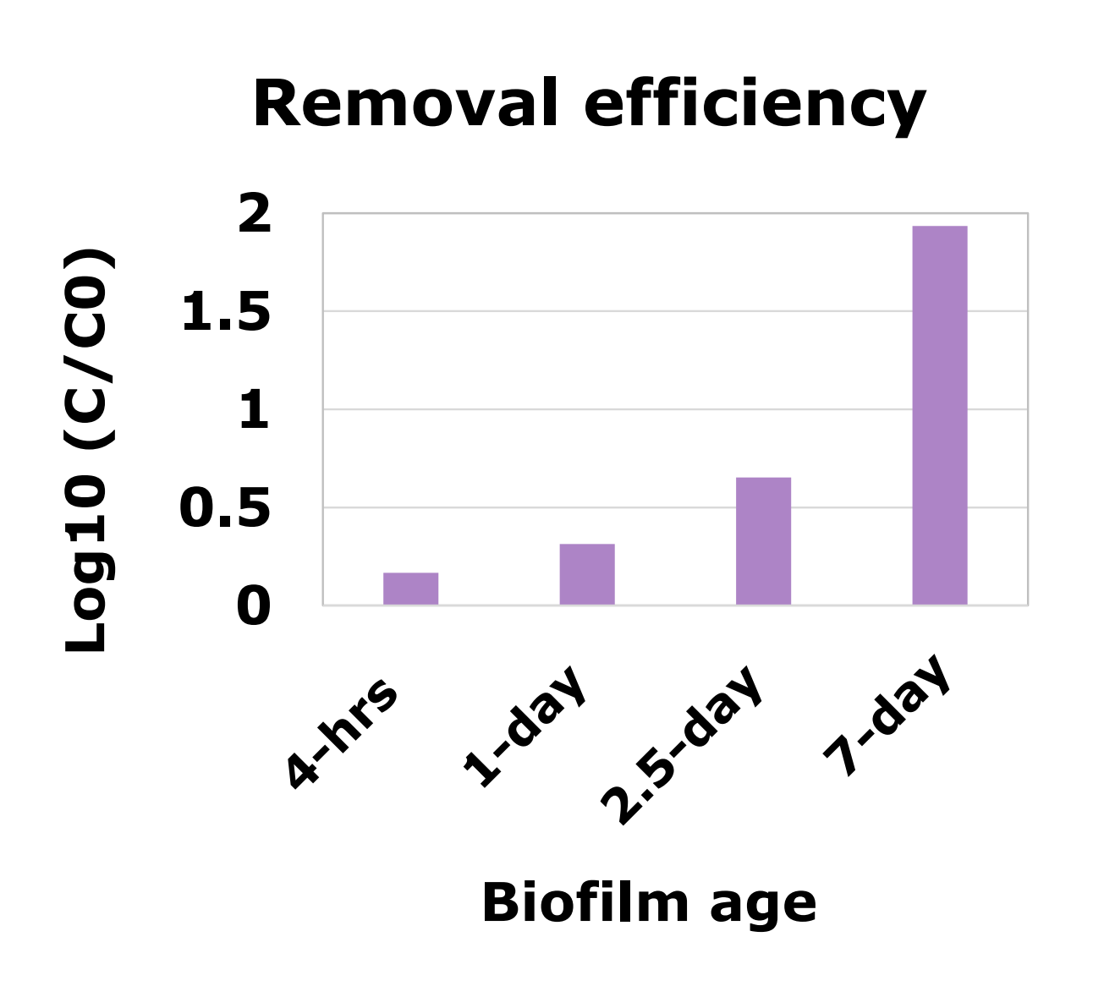

Figure 6: **Removal efficiency of 1.5 µm colloids in the models with biofilms of various ages**

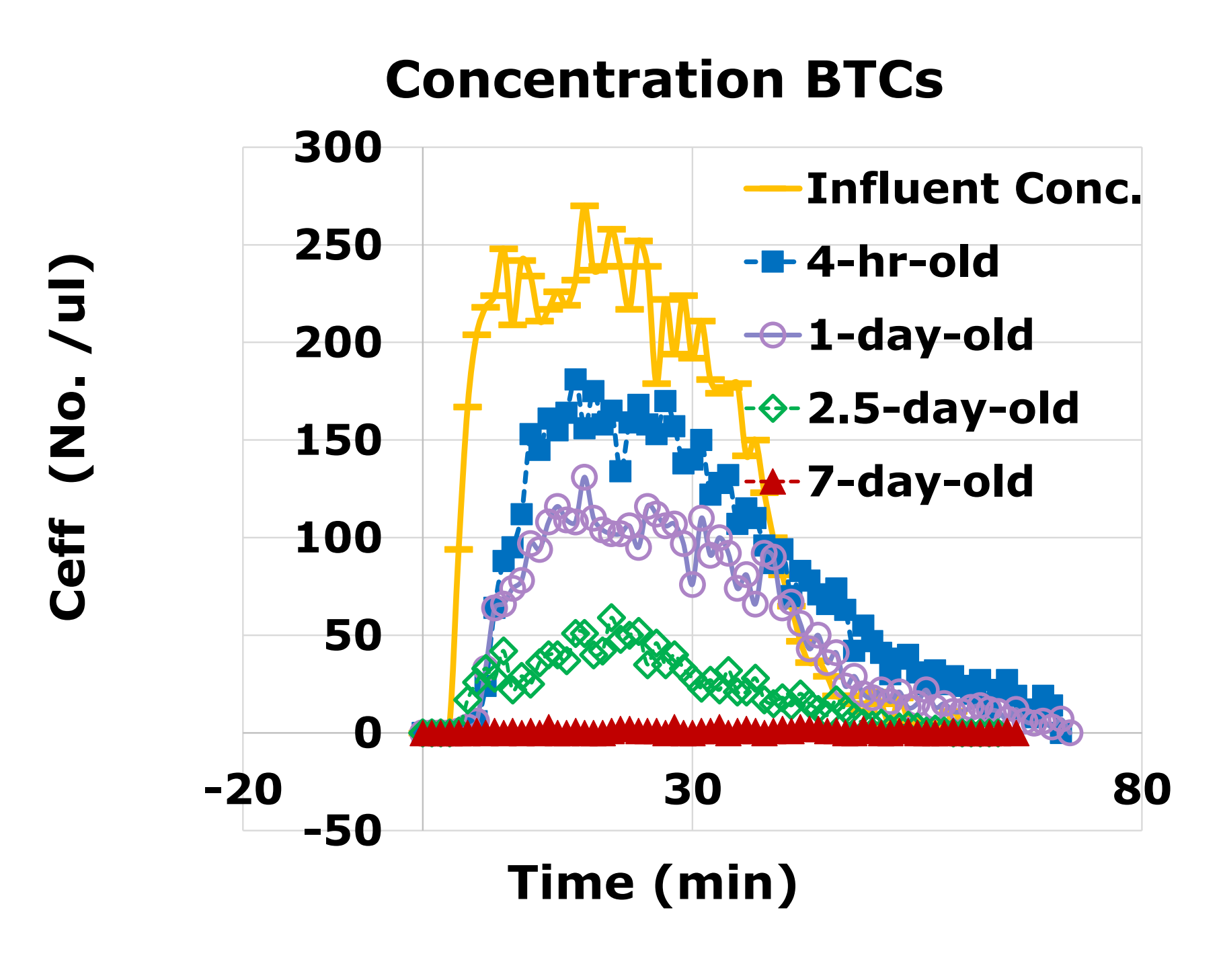

Figure 7: **BTCs of 1.5 µm colloids at the micro models effluent**

Biofilm morphology - Confocal microscopy imaging

❑ Biofilms showed rough, irregular structures with interior pores which elevated colloids removal efficiency.

❑ Biofilm growth changed pores size distribution and connectivity which resulted in various removal mechanisms such as collision and straining.

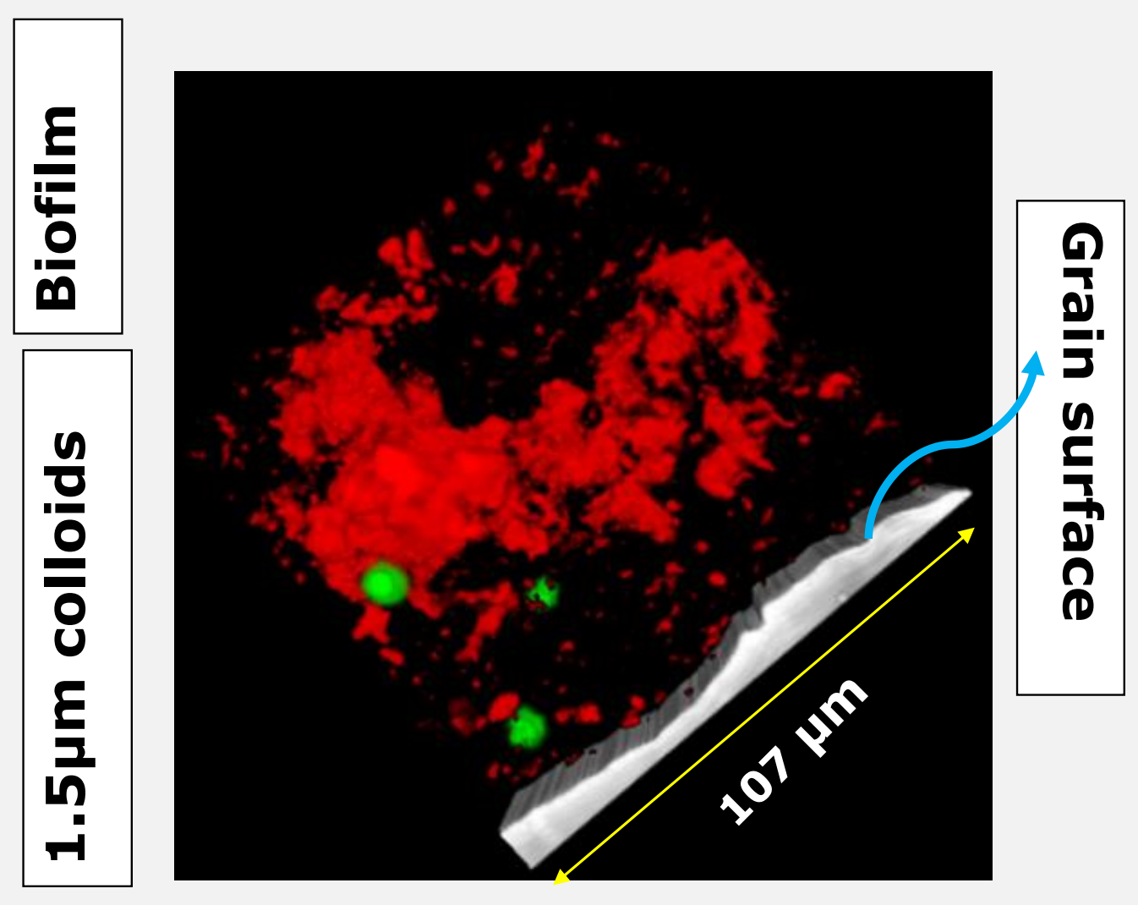

Figure 8: **Trapped colloids inside the rough structure of biofilm**

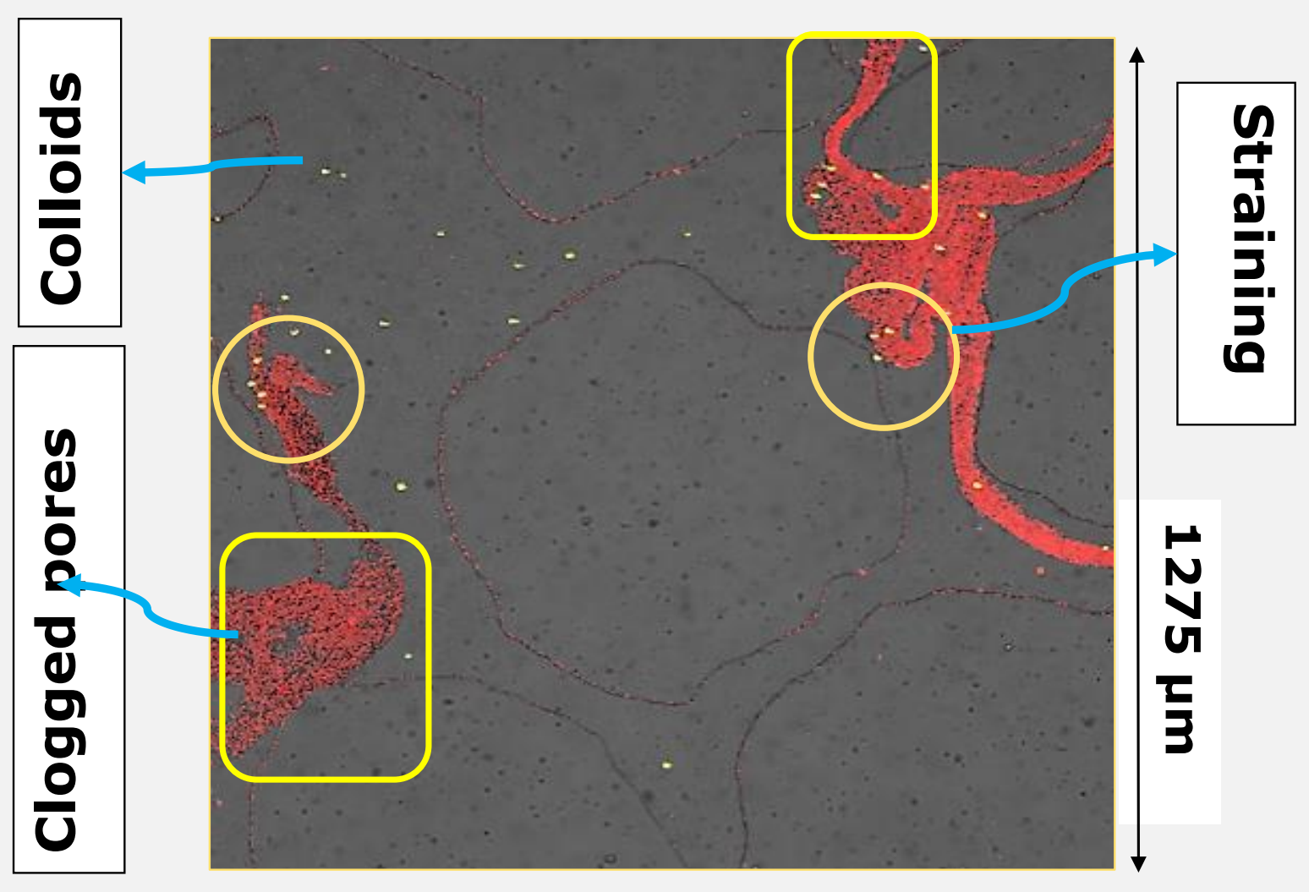

Figure 9: **Straining of colloids due to biofilm growth inside the pores**

Preferential flow paths - Fluorescent microscopy imaging

❑ Biofilm growth made preferential flow paths by clogging some of the pores.

❑ Colloids are Forced the to move towards the open pores with lower resistance.

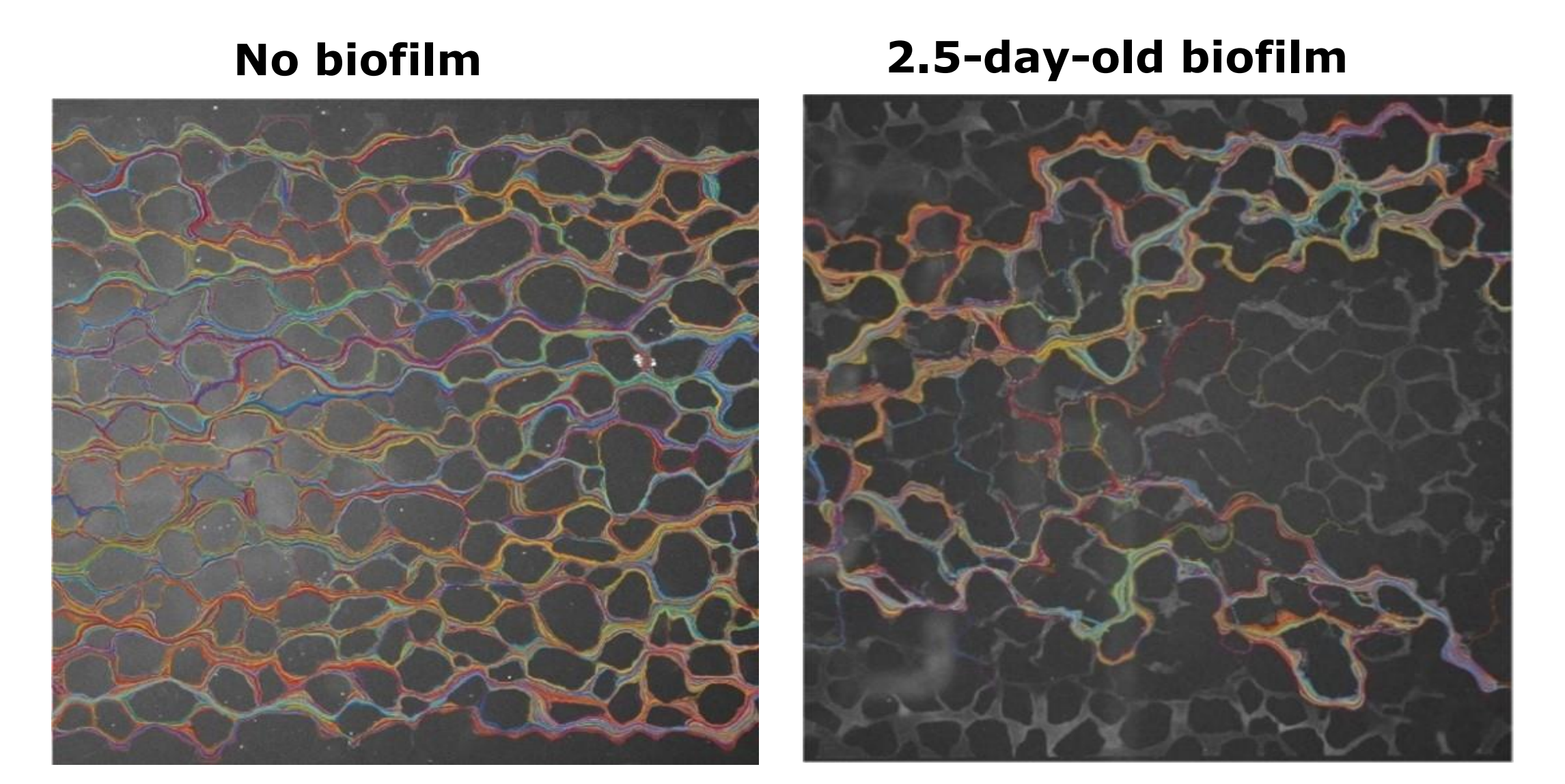

Figure 10: **Colloid trajectories and created preferential flow paths due to biofilm growth**

Conclusions

The main findings showed that biofilm growth

- ➢ substantially enhanced colloid removal efficiency
- ➢ altered pore and throat size distributions
- ➢ resulted in different removal mechanisms including collision, and straining
- ➢ impacted flow hydrodynamics and created preferential flow paths

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