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# *Colloid transport inside slow sand filters: A multiscale study*

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## Introduction

✓ Fate and transport of colloids such as pathogenic microorganisms in subsurface environment is crucial to protect public health from waterborne diseases.

✓ Biofilm growth in aquatic systems can affect colloids transport and retention processes by altering collectors surface properties, porosity and permeability of the media.

✓ Slow Sand Filters are used in producing drinking water. A bioactive layer on top of these filters, called the Schmutzdecke, plays an effective role in colloid removal efficiency.

✓ A multi scale study is performed to investigate the role of the bioactive layer and attachment mechanisms inside slow sand filters.

**Figure 1: Bioactive layer on top of a drained slow sand filter**

## Pilot scale spiking experiments

### Methods

✓ High titer *E.coli* WR1 was spiked into the filter for 22 hours.

✓ *E.coli* concentration in influent water was increased to 1.0E5 CFU/ml.

✓ Water samples were taken at influent, 10cm and 80cm below the sand surface for 7 days to measure *E.coli* removal efficiency.

**Figure 2: Pilot scale filters which represent real scale slow sand filters**

### Results

✓ The filter total Log removal efficiency was 1.65.

✓ The top 10cm of the sand, including the bioactive layer, showed 1.28 Log removal value.

✓ The last 70cm of the sand showed 0.36 Log removal value.

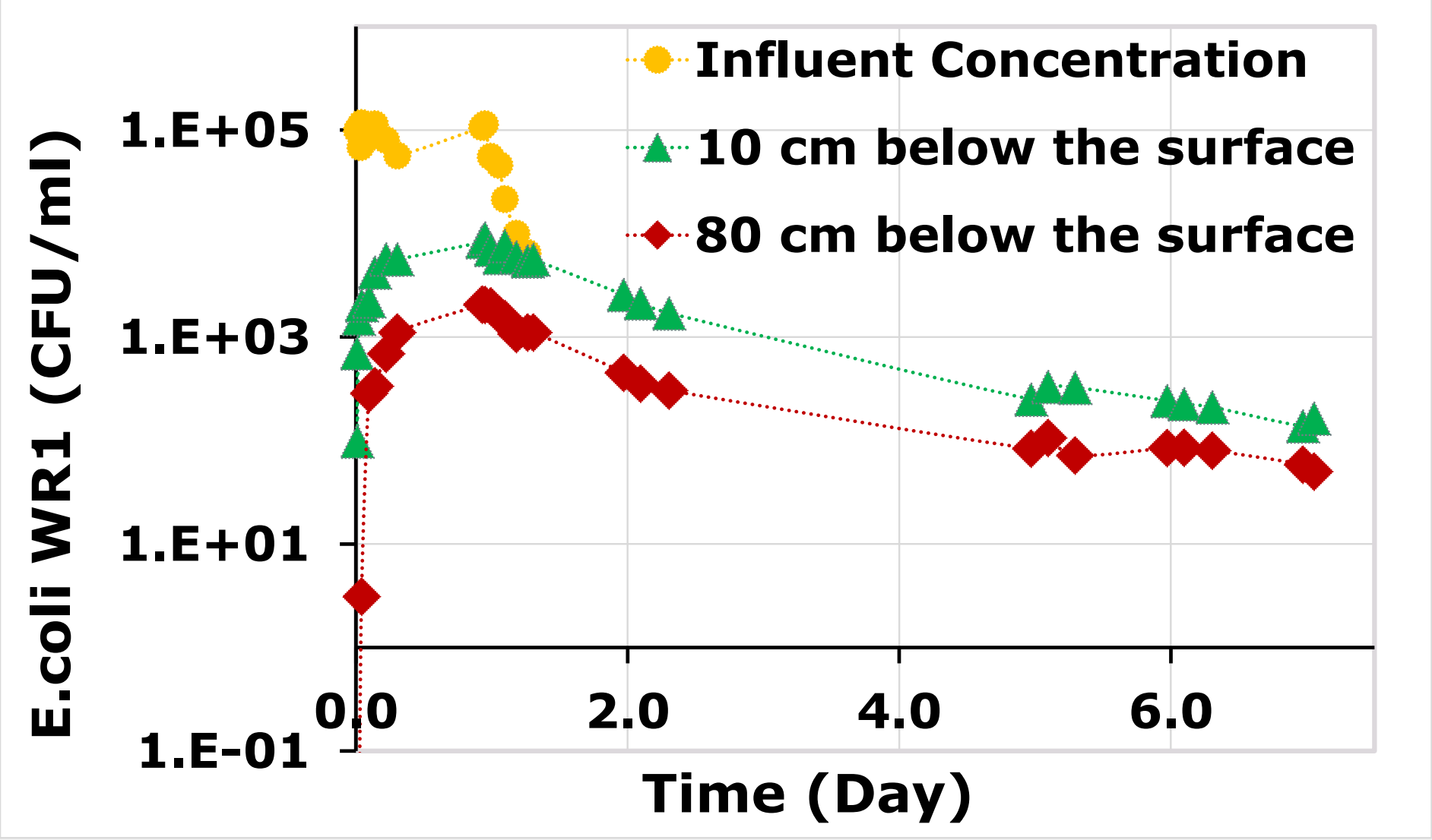

**Figure 3: *E.coli* BTCs obtained at 10cm and 80cm below the sand surface at a pilot scale filter**

## Micro scale experiments: Sand filter on chip

### Advantages of using microfluidics

❑ Direct observation of biomass development, and morphology

❑ Direct observation of colloids and biomass interactions

❑ Helps to gain insight into pore-scale processes and various attachment mechanisms

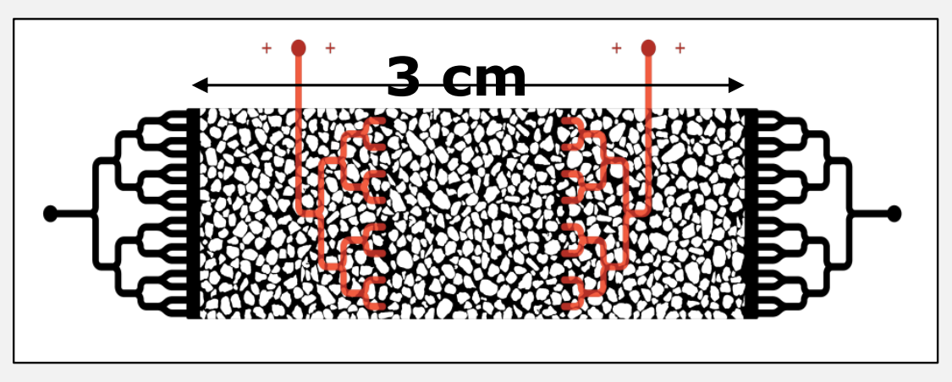

**Figure 4: microfluidic devices**

### Methods

❑ Biofilms of different age/maturity were developed within microfluidics

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

❑ Fluorescent imaging coupled with image analysis was used to track colloids within the models

❑ Biofilm was stained with Concanavalin A and observed under confocal microscopy

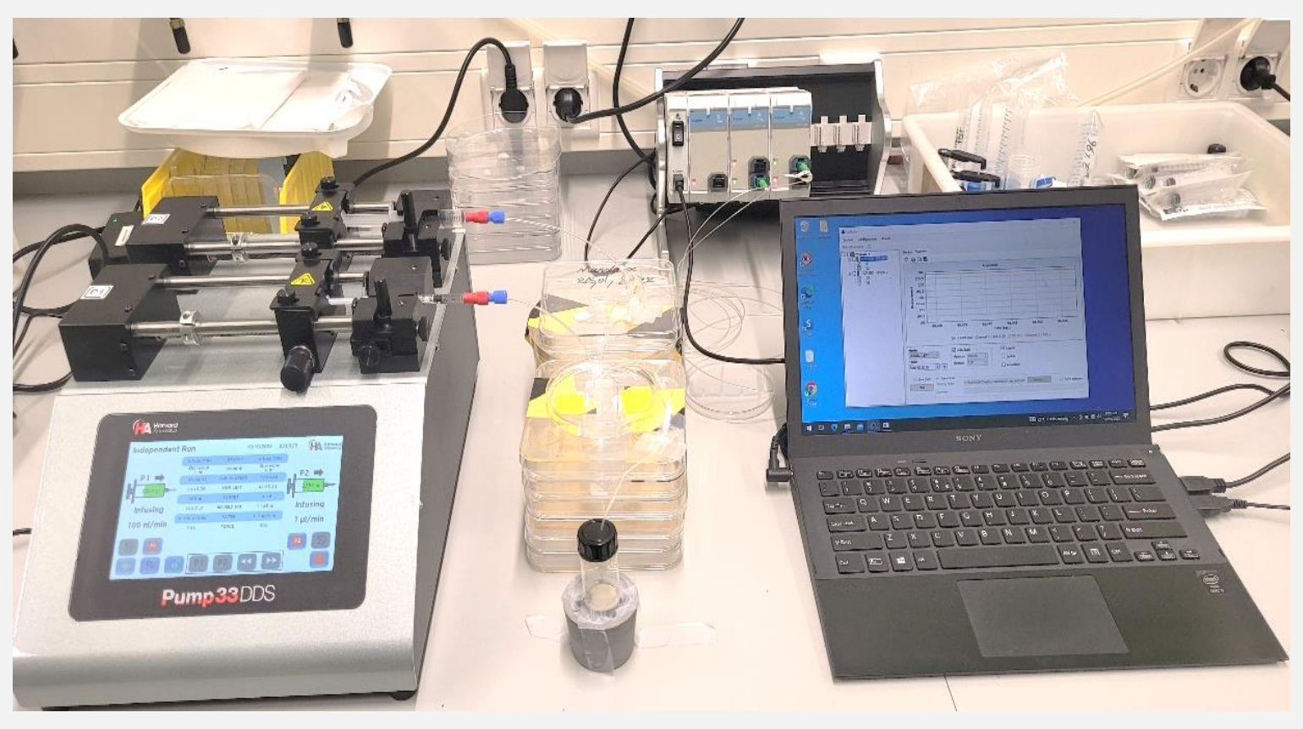

**Figure 5: Setup of biofilm growth**

## Results

### BTCs

❑ Log removal efficiency of 1.5µm 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.

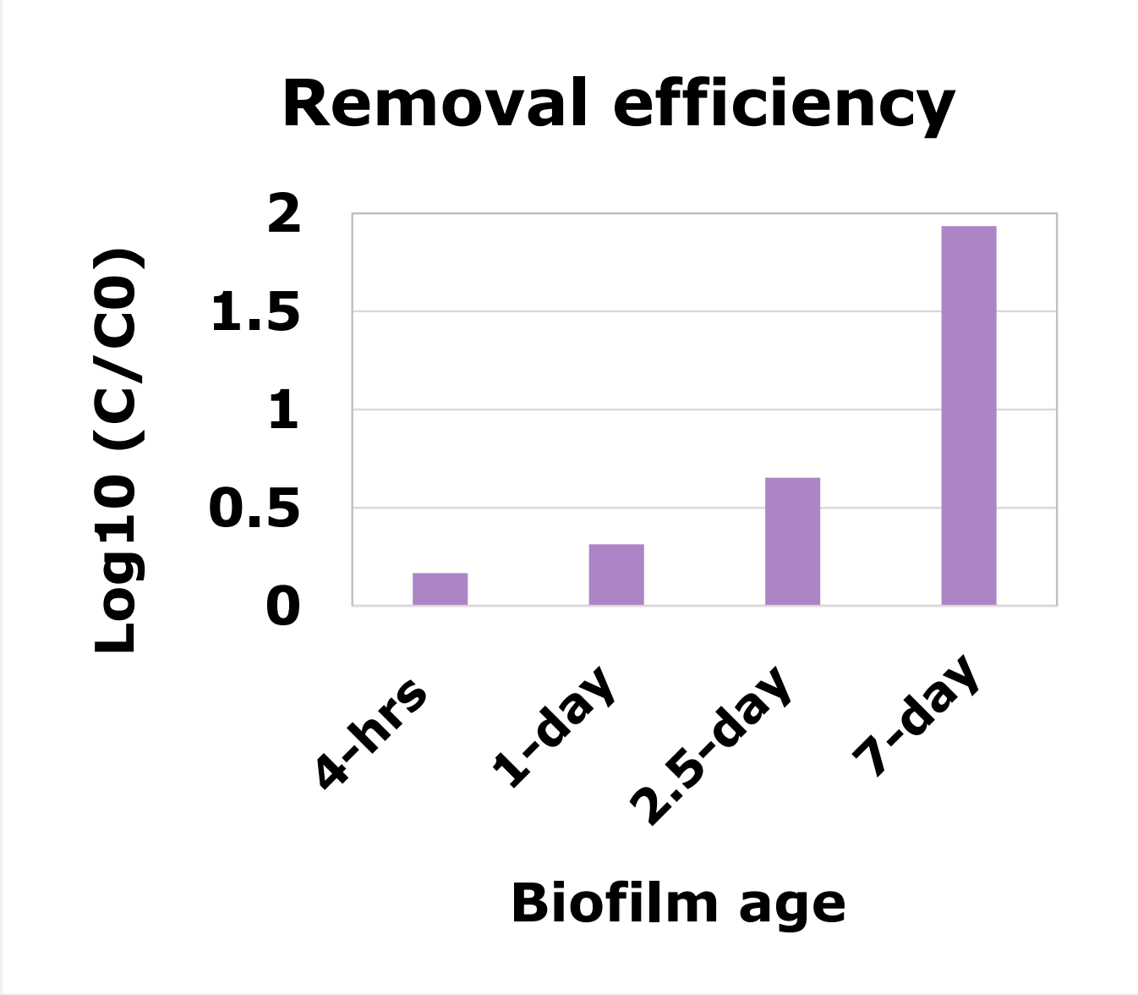

**Figure 6: Removal efficiency of 1.5µm colloids inside the models with biofilms of various age**

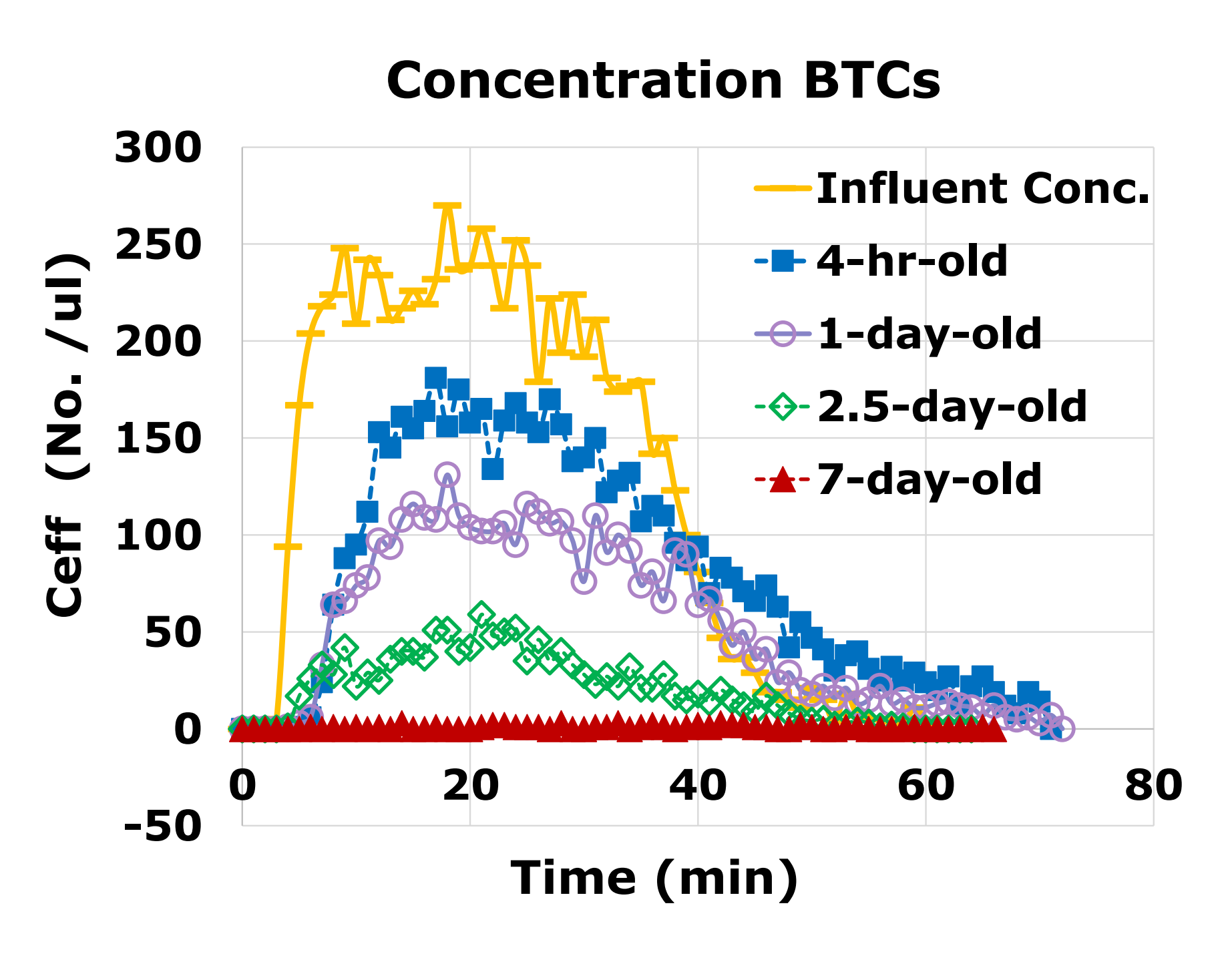

**Figure 7: 1.5µm colloids BTCs obtained at the effluent of microfluidic devices**

## 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.

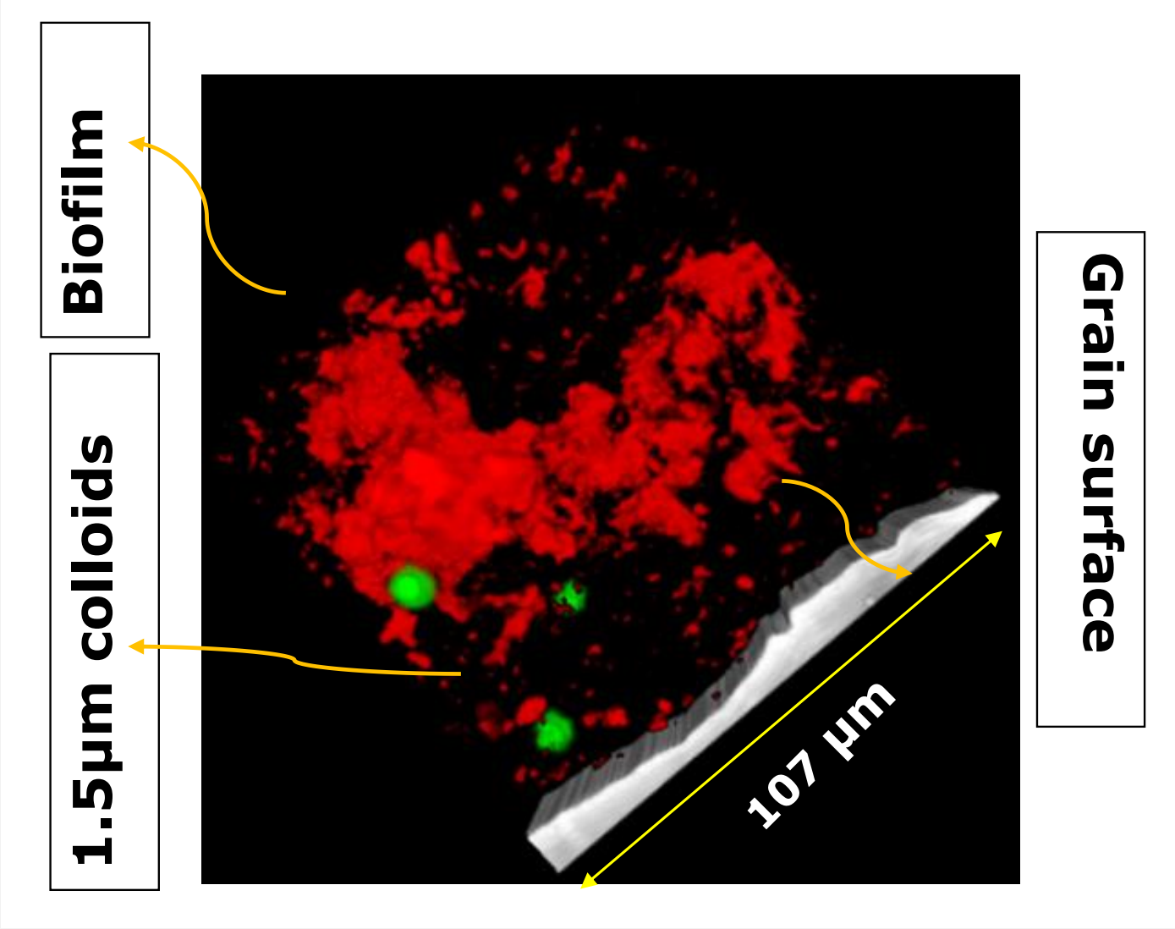

**Figure 8: Trapped colloids inside the rough structure of biofilm**

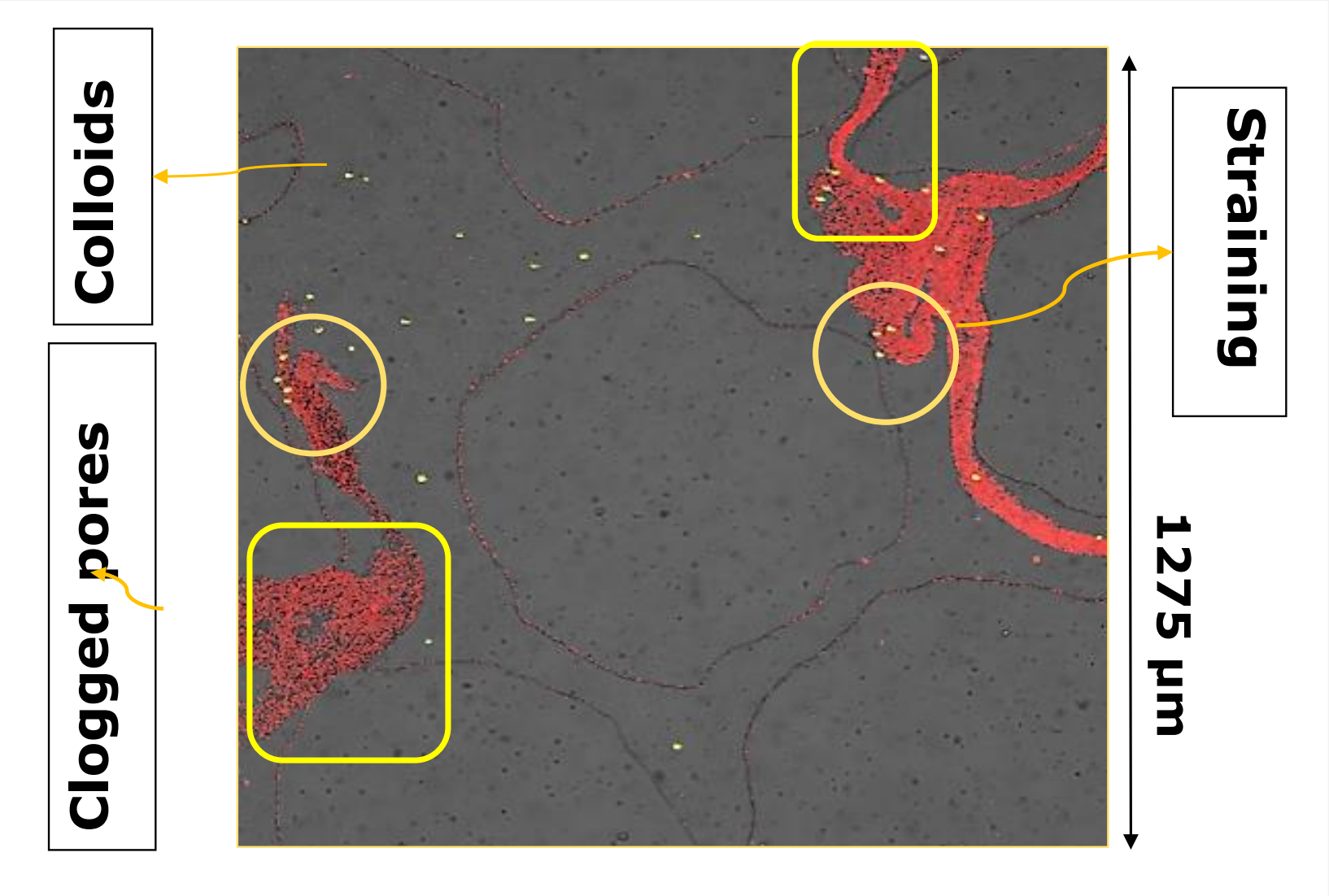

**Figure 9: Straining of colloids due to biofilm growth inside the pores**

## Preferential flow paths - Fluorescent microscopy imaging

❑ Biofilm growth made preferential flow paths by clogging some of the pores and forcing the colloids to move towards the open pores.

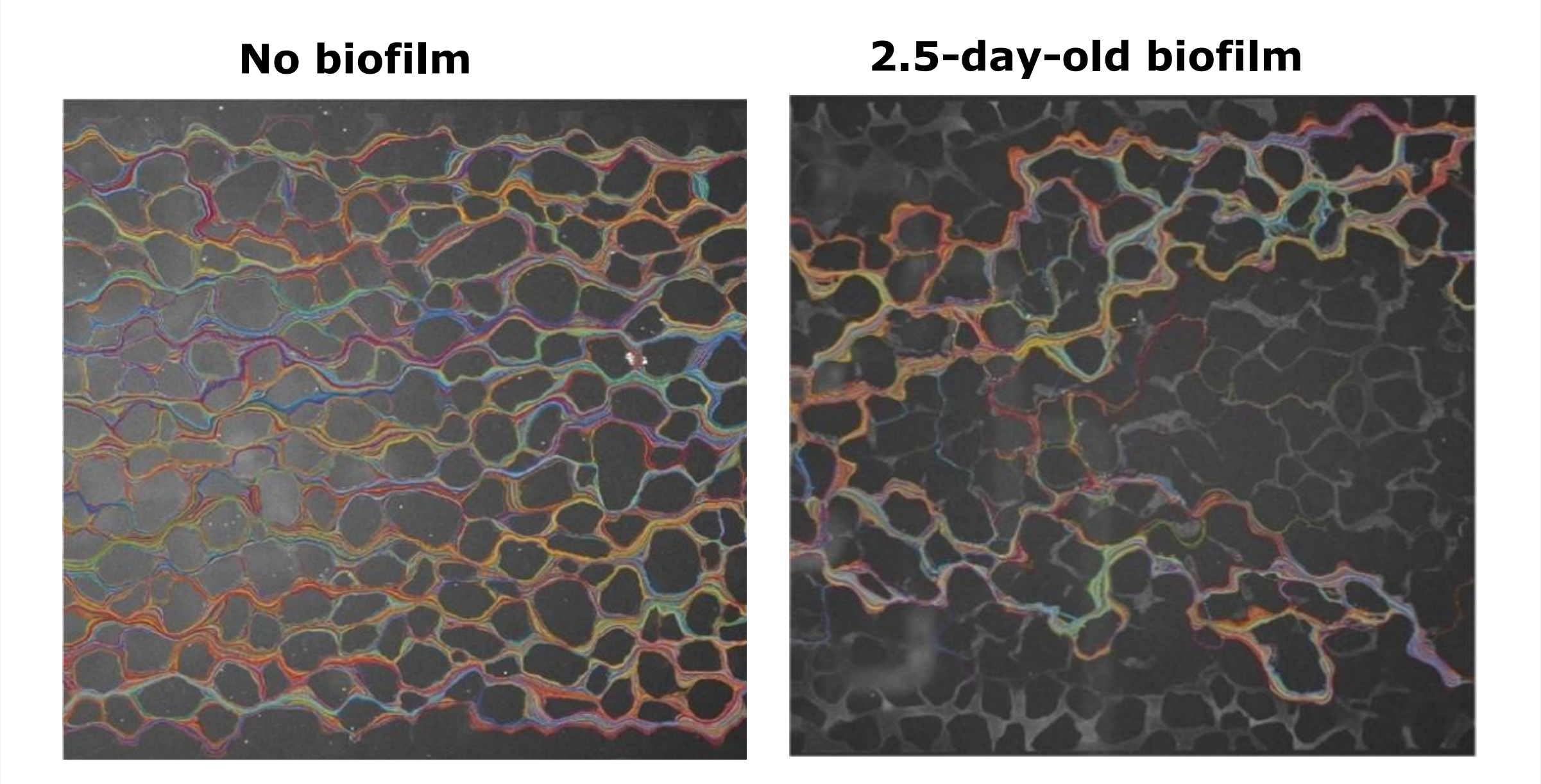

**Figure 10: Colloid trajectories and preferential flow paths created inside the domain due to biofilm growth**

## 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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