Surface-washing of contaminated porous substrates

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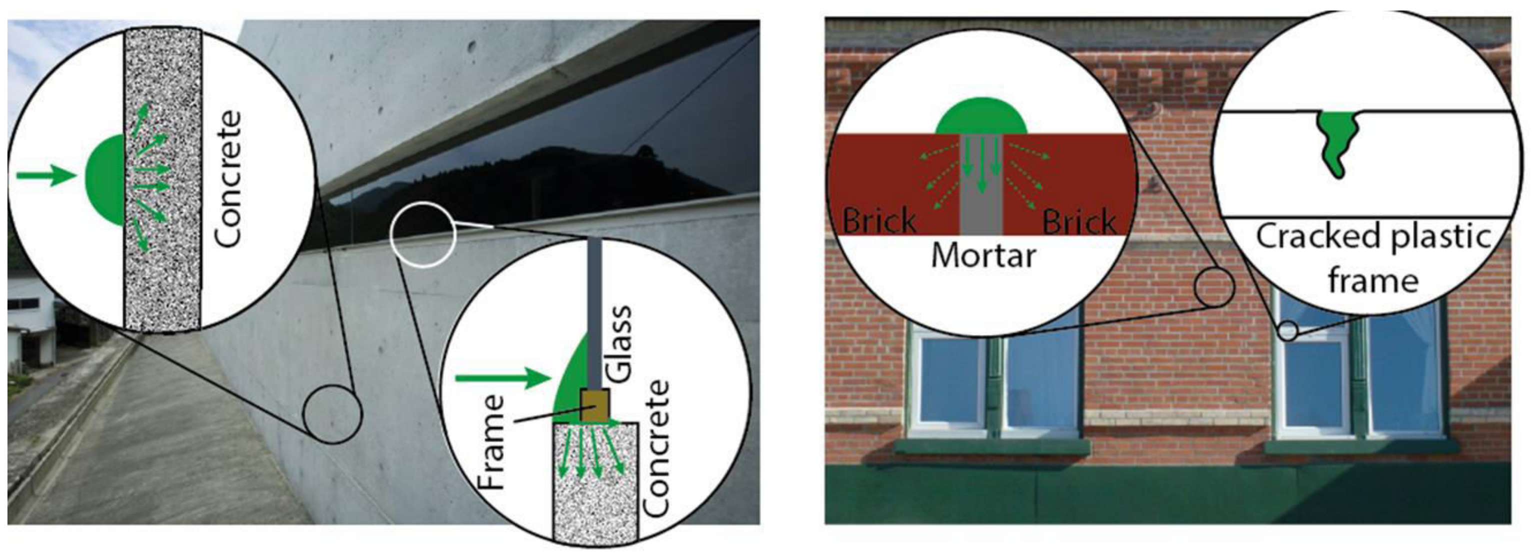
Introduction

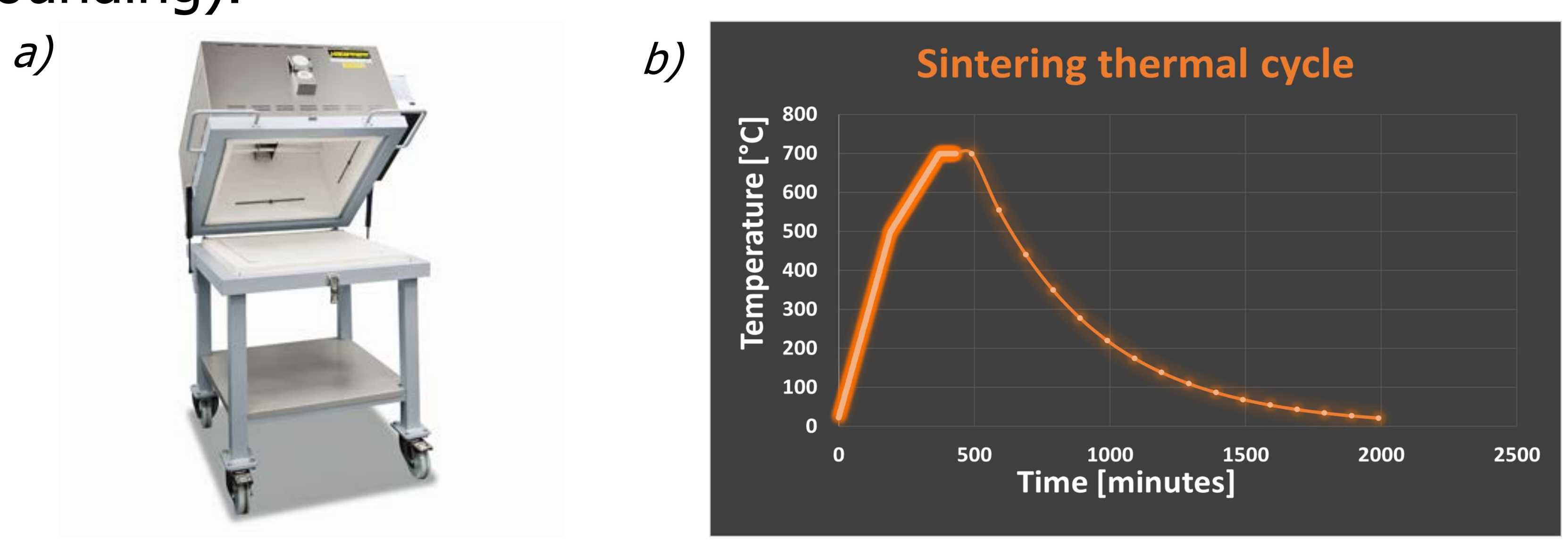
Depending on several factors such as cleaning strategies, initial conditions and agents' chemical nature, the decontamination processes of porous surfaces can lead to a partial redistribution of the contaminant within the porous matrix instead of a complete removal of the unwanted substance [1].



Examples of cleaning and decontamination challenges in an urban environment.

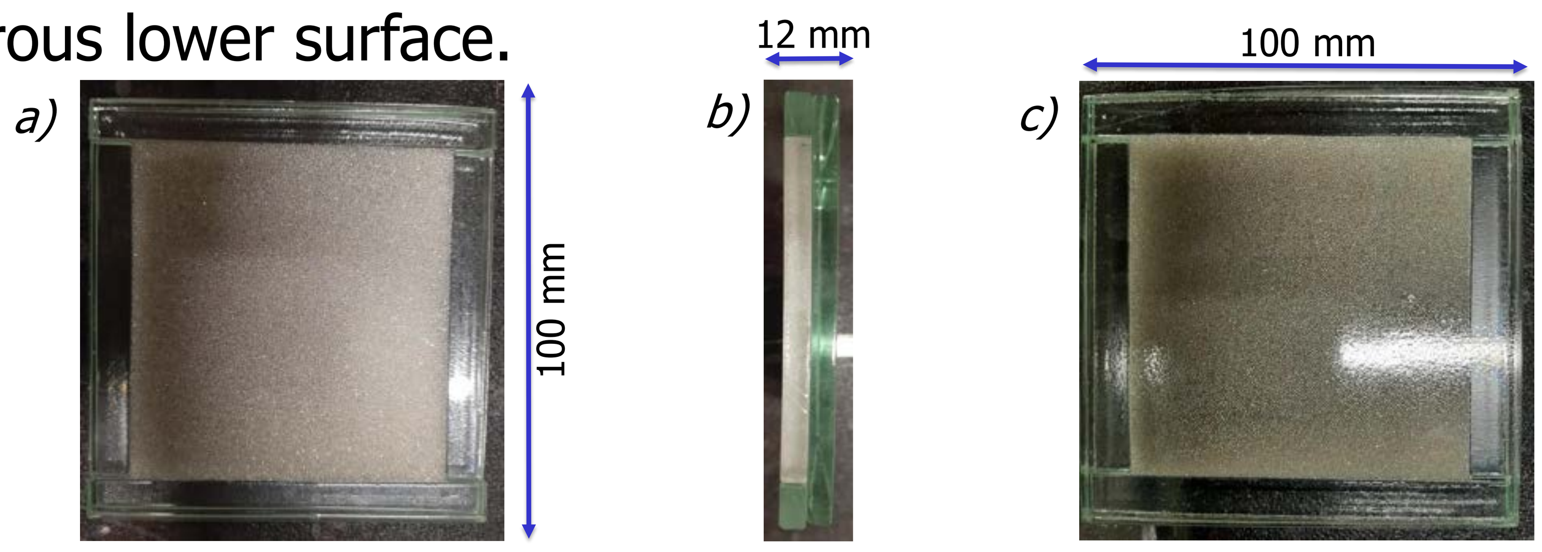
Porous media production: sintering on glass

We have validated a protocol to manufacture well-defined porous media by sintering soda-lime glass beads (< 1 mm) to form mechanically stable homogeneous porous plates incorporated in a non-porous solid glass frame (backing and surrounding).



a) Glass fusing kiln "Nabertherm GF75";
b) Sintering thermal cycle to produce solid porous samples from glass ballotini.

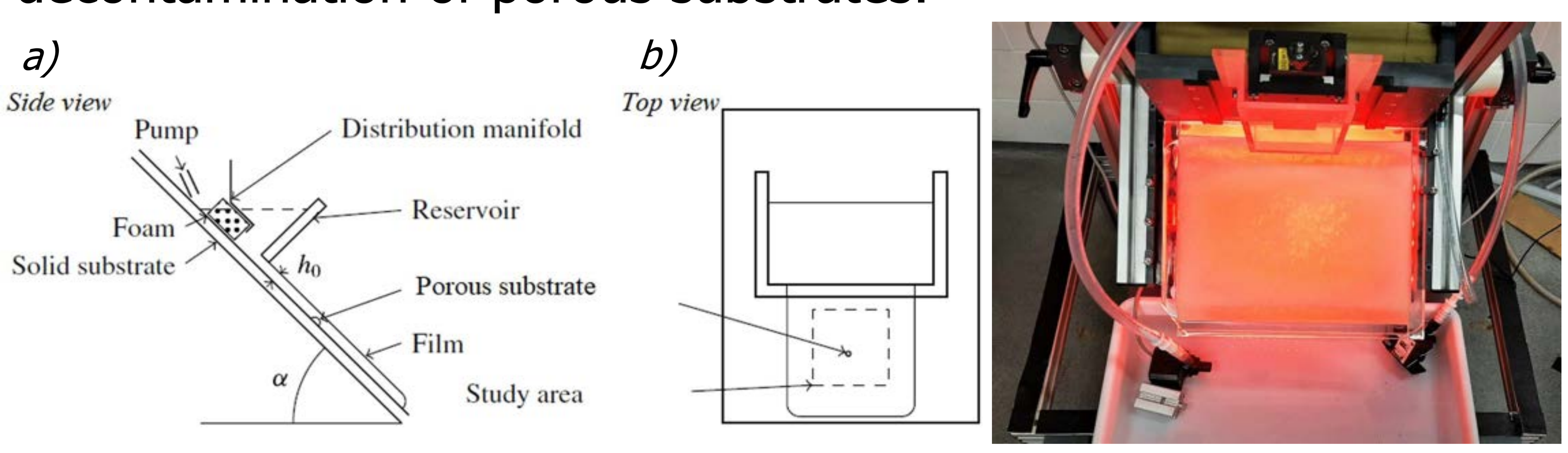
The solid glass backing prevents any liquid leaks through the porous lower surface.



Rigid porous medium incorporated in solid glass plates: a) top, b) side, and c) back views.

Experimental setup

The manufactured porous plates are integrated into the apparatus described in [2] to study surface-washing decontamination of porous substrates.

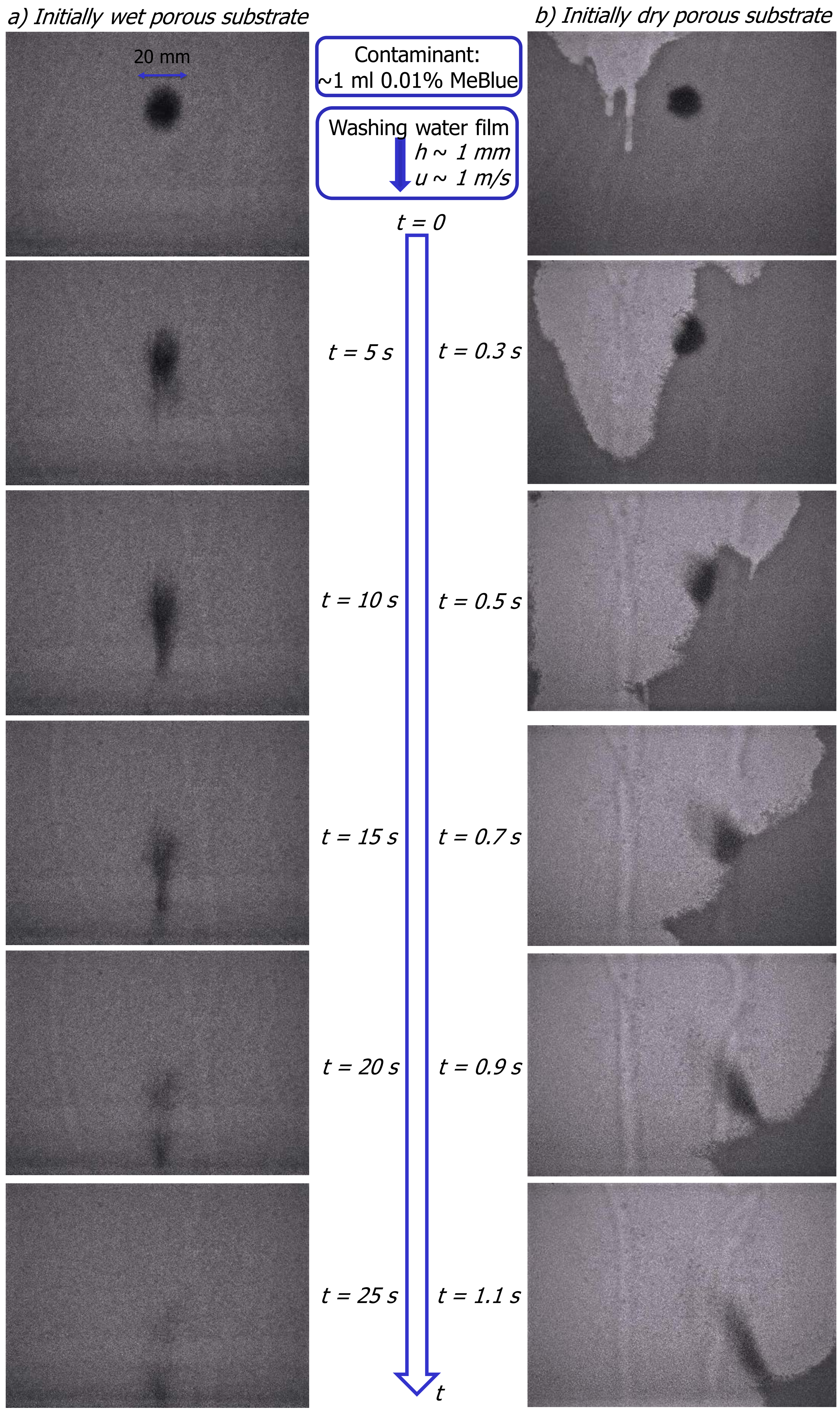


Scheme of the experimental apparatus: (a) side view; (b) top view.

The surface is inclined of $\alpha \sim 30°$ with respect to the horizontal plane. A ~1 ml droplet of a dyed fluid (MeBlue, fluorescein, Hexyl) is released onto the porous substrate to simulate the contaminated region, and a thin (h ~ 1 mm) gravity-driven water film flows over the surface as a decontaminant flow. A light source (LEDs arrays) is placed underneath together with a diffuser, and a camera records the flow in the study area.

Dye-attenuation technique

The fluid mechanics of decontamination (advection-diffusion of the contaminant dye in the cleansing fluid and in the porous medium) is tracked using dye-attenuation and/or fluorescence techniques. Such methods enable to analyse the contaminant concentration field in space and time.



a) The dye removal is primarily due to the gravity-driven advection in the decontaminant film and within the porous medium (the contaminated region is elongated in the flow direction).
b) The contaminant, initially absorbed into the porous matrix, is transported within the substrate by the capillary-driven wetting front of the imbibing decontaminant liquid.

The experiments clearly demonstrate a decontamination-induced redistribution of the contaminant within the porous medium.

Work in progress

We are developing a characterisation method for the porous media properties. This will enable a systematic analysis of the decontamination process and a quantitative comparison between our experimental data and numerical simulations (COMSOL).

References

[1] Landel, JR, Wilson, DI (2021) "The fluid mechanics of cleaning and decontamination of surfaces". Annu. Rev. Fluid Mech. 53, 147-171.
[2] Landel, JR, Thomas, A, McEvoy, H, Dalziel, S (2016) "Convective mass transfer from a submerged drop in a thin falling film". J. Fluid Mech. 789, 630–668.