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Modelling surface-washing of porous media: dye-attenuation of a passive tracer

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The cleaning and decontamination of various porous surfaces (e.g., concrete, tarmac, wood, etc.) is a challenging and multidisciplinary problem for both fundamental understanding and a wide range of industrial, medical, urban, everyday-life and disaster-response applications [1]. The role of such processes is particularly crucial in cases where contaminants (such as chemical substances and biological pathogens) are extremely harmful and pose serious risks to human health. Indeed, attempts to decontaminate porous materials might lead to a partial redistribution of the unwanted substance within the porous matrix instead of a complete removal. As a result, cleaning operations could further contribute to the contaminant/pathogen spread, and the substance might remain a long-term hazard for people coming in contact with the contaminated medium.
In this work, we present surface-washing experiments modelling the decontamination of porous media using a rig equipped with camera-based (spatially resolved) and in-line UV-Vis diagnostics.
The model porous surfaces used are manufactured in our laboratory by sintering packings of soda-lime glass beads of various size distributions onto solid glass frames. The obtained composite structures are then directly incorporated in a surface-washing apparatus [2].
The contaminant agent is simulated by a dyed passive tracer, either disodium-fluorescein or methylene blue. These aqueous solutions are released onto the free porous surface of a water-saturated medium in the form of droplets. The surface-washing is simulated by a thin gravity-driven water film flowing over the inclined porous-glass plane.
The space-time evolution of the contaminant field across the porous medium and its interaction with the cleansing flow are then tracked by direct image analysis based on dye-attenuation using multi-wavelength illumination spectra. This technique enables us to study the tracer spreading (advection, diffusion, dispersion, and absorption) over a wide range of concentrations. Additionally, an inline UV-Vis spectrometer is used to monitor in real-time the contaminant concentration in the washing effluent.
Our experiments provide insights into the fundamental physics governing the cleaning process, such as the role of initial conditions (e.g., ingress of contaminant, wet/dry substrate) and the impact of process parameters on the decontamination efficiency (e.g., necessary amount of cleansing resources and washing time). Importantly, they demonstrate a decontamination-induced redistribution of the contaminant within the porous matrix.
Finally, we provide some fundamental considerations regarding the choice of the optical method in a dye-attenuation context. In particular, we discuss how the factors such as the light source, the dye absorbance, the camera-response, and the medium void-fraction distributions complicate the accurate tracking of the contaminant simulant.

Participation

In-Person

References

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