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Development of a tridimensional characterization methodology for hierarchical materials: application to the nuclear effluent decontamination in fixed-bed processes.

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Hierarchically structured materials consist in multiphase (crystalline-amorphous) materials also presenting a multiscale porosity. Such materials are widely used for the decontamination of liquid effluents in fixed-bed processes. Indeed, charge-compensating ions in their structure allow them to perform a selective cationic exchange. Their decontamination efficiencies are finely determined using static and dynamic experiments [1]. However, no precise link between their decontamination performances in fixed-bed processes and their multi-scale microstructure has been identified yet. In this way, this project aims to develop reproducible methods and protocols to finely analyze the tridimensional microstructure of hierarchical materials at different scales and correlate these quantitative data to the decontamination properties (thermodynamics, kinetics and hydrodynamic).

For that purpose, the development of efficient characterization methodologies involves the use of different cutting-edge techniques. On the one hand, the way to follow and analyze precisely the various scales of porosity and the localization of the different phases of the materials was identified. On the other hand, the use of numerical methods is necessary to process and combine data to extract key parameters describing the microstructural architecture of these hierarchical materials as finely as possible.

These developments are performed on model materials with adjustable properties. Notably, zeolite powder hosting selective active sites for Cesium has been embedded in a multiporous geopolymer matrix [2]. Techniques such as electron microscopy (2D), electron microscopy with focused ion beam (3D) and X-ray tomography (3D) are used. Image segmentation is performed thanks to advanced numerical methods involving machine learning, which enhance the efficiency and the precision of the process. Various image processing softwares provide numerical values of different morphological parameters impacting the decontamination efficiency like the geometry and tortuosity of the porous network or the localization and accessibility of "active" sites for the decontamination. Correlative data processing will consist in improving data from one imaging technique thanks to results from another. This allows to better investigate the various scales of porosity and their impacts upon the decontamination properties of these hierarchical materials.

Participation

In-Person

References

[1] A. Grandjean, et al., Process Safety and Environmental Protection, 134, (2020), 371-380.

[2] Proust, V. et al., J. Water Process. Engineering, 51 (2023) 103381.

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