Features of transports in nano-porous media - Contribution of NMR and MRI

Philippe Coussot*[1]

[1]Laboratoire Navier – Ecole des Ponts ParisTech, Centre National de la Recherche Scientifique, Université Gustave Eiffel – France

Résumé

Many porous materials such as concretes, soils, wood, etc, contain at least a fraction of nanopores. The transports in these nanopores play an important role for various energy transfers (osmotic transport, energy storage, hygrothermal behavior of bio-based materials, etc). However, the flow properties at this scale, even in straight channels, are complex (1), in particular as the continuum assumption may be invalid, and the interactions of molecules with solid surfaces can play a major role. We can therefore expect original transport properties in non-model porous media, possibly multi-scale, with also the possibility of exchanges between the different pore sizes, but observations or measurements at this scale are tricky. NMR relaxometry offers the possibility to obtain precise quantitative (statistical) information concerning the liquid distribution in the different pore types. Moreover, this technique makes it possible to follow the evolutions of pore size, surface wetting, or even exchanges between different porous phases (2). In addition, the spatial distribution of liquid in the different types of pores can be measured using appropriate MRI sequences (3).

It is thus shown that the desaturation of a silica glass (Vycor) results from a vapor pressure gradient associated with local saturation and inducing a pressure gradient in the liquid, leading globally to a diffusion mechanism (4). In a "bi-porous" material formed of nanoporous inclusions and micrometric pores, it is shown that the liquid contained in the large pores is drained in depth and transported through the nanopores, which are therefore emptied last (2). NMR also makes it possible to measure the distribution of bound water absorbed in the form of nanometric inclusions in the amorphous regions of the cellulose of bio-sourced materials. It can then be observed that the drying of wood relies on the diffusion of bound water, which first extracts the free water from the fibers, vessels or tracheids, and transports it to the free surface (3). Finally, this bound water appears to be very mobile: its diffusion coefficient, which can be directly measured by blocking the transport of free water, is higher than the self-diffusion coefficient of water.

References

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*Intervenant

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