Imaging fluid transfers in pores and pore changes through dynamic NMR relaxometry

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Introduction.

Interaction liquid water porous media → Key concept for building materials

IRM and other imagery techniques → Qualitative local information

Using colloidal deposition to mobilize immiscible fluids from porous media
Joanna Schneider, Rodney D. Priestley, and Sujit S. Datta
Phys. Rev. Fluids, 2021


« Dynamic » NMR → No invasive multiscale quantitative full description of water transfer over time
The relaxation time in porous media

Tarr and Brownstein theory (1978):
\[
\frac{1}{T_{2, \text{pore}}} \cdot \frac{1}{T_{2, \text{pure liquide}}} = \rho_2 \cdot \frac{S_{\text{wet}}}{V_{\text{water}}}
\]

If small pore
If fast exchange bulk water and surface water.

\[
\Rightarrow A \propto V_{\text{water}}
\]
\[
\Rightarrow T_2 \approx \text{cste} \cdot \frac{V_{\text{water}}}{S_{\text{wet}}}
\]
NMR and MRI, a non-destructive method in time resolved.

Minispec Bruker
0.5 teslas
+ Gradient

Ex: Drying of a piece of wood (≈ 1 cm³)
Expected results...

\( T_2 \propto \psi^{1/3} \)

\( \Psi: \text{saturation} \)

\( T_2 \propto \psi \)

\( T_2 \approx \text{Const.} \)

\( \langle T_2 \rangle \)

\( \sigma(T_2) \)
Vycor Imbibition

Philippe Coussot
Patrick Huber
Benjamin Maillet
Guido Dittrich
2022

« Dry » pore

Saturated pore

Adsorbed water
Fast exchange
Non adsorbed water

Dry

1D Profiles

Vycor (pore size ≈ 3 nm)

Water bath

Total water

Drying time (h)

Adsorbed + non adsorbed water

T2 (ms)

T2 distributions
**Vycor drying**

- 1D Profiles
- $T_2$ distributions

**Saturation (%)**

- $T_2 \propto a^3$ and $A \propto a^3$ → $S$(wet) constant

**Dry air**

- Adsorbed + non adsorbed water

- Adsorbed water

- Dry air
Biporous material drying

*T2 distributions*

\[ T_2 \propto a \quad \text{and} \quad A \propto a^3 \]

\[ \psi \]

\[ \psi_1 \]

\[ \psi_2 \]

\[ \tau \]

\[ \tau/\theta \]

Isotropic contraction

\[ \text{Slope power } 1/3 \]
Recent publication (2022).

Two-step diffusion in cellular hygroscopic (vascular plant-like) materials

Marion Cocusse, Matteo Rosales, Benjamin Maillet, Rahima Sidi-Boulenouar, Elisa Julien, Sabine Carè, Philippe Coussot

Weak drying

$T_2$ (free water) constant.
$\rightarrow$ Total dewetting for tracheids

$T_2$ (bound water) decreases.
$\rightarrow$ In accordance with contraction

$MC_0$: Initial moisture content
$MC$: Moisture content
To conclude…

Dynamic relaxometry
\[ \rightarrow \text{Efficient and original methodology to describe fully liquid transfer.} \]
\[ \rightarrow \text{Time resolved multiscale global and/or local analytic informations.} \]

… thanks to T2 distributions \( A(t), \text{coupling } T_2(t) - A(t), \text{FWHM}(t), \text{for each population of water} \) and profiles.

Extended to all the water or protonic liquid transfers.

Direct validation of transfer models allowed!
Thanks for your attention!
Drying of 2 layers glass bead packing

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Jérôme Suard
2022

1D Profiles

0.5 µm interstitial water
2 µm interstitial water

Saturation (%)

0.5 µm intersticial water
2 µm interstitial water

T2 distributions