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# Freezing and Thawing Process in Porous Media: A Study Using Magnetic Resonance Imaging and Modeling

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Freezing and thawing of water in porous media depend on pore size distribution and shape of particles. Magnetic resonance imaging (MRI) of the freezing and thawing process was performed on two samples of different porous materials, each one in two replicates. The experiment was subsequently numerically simulated. The set-up consisted of a double-walled Plexiglas container. The inner cylindrical container (3 cm inner diameter, 6 cm high) was filled with the sample material. On the top of the porous media, a glass disk (2.8 cm in diameter, 1 cm thickness) was placed to define the upper boundary of the material during freezing and thawing. One inflow tube and two outflow tubes at the top of the inner cylinder were used for the circulation of cold nitrogen gas as a freezing medium to the top of the sample. The temperatures of the freezing medium were continuously recorded by the temperature sensors located outside of the MR coil. The first sample packing consisted of 72 glass beads, 0.8 cm in diameter immersed in the 1 mM/L GdDTPa2-·2Na+. In the second sample, the coarse sand was packed in 0.5 cm thick layers in the same sample solute. A total of eight freezing-thawing cycles were performed and recorded on the samples. As a result, time-lapse series of 3D MR images were obtained. The analyses of the freezing-thawing process on glass beads revealed interesting effects while thawing, where the thin layers on the glass beads surface exhibited faster melting in otherwise homogeneous ice. The freezing-thawing fronts recorded of sand samples were relatively uniform. The spatiotemporal analysis of the frozen water volume is done.
Numerical simulation of the observed phenomena is performed by the model based on the conservation of mass, energy, and momentum solved by the finite-element method. The model provides information on the distribution of temperature, both phases and on structural changes in the porous structure caused by the phase transition. The model serves for better understanding of observed phenomena and optimization of the experiments.

## Participation

In-Person

## References

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