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Nuclear magnetic resonance relaxation and diffusion measurements as a proxy for soil properties

Markus Duschl (1), Andreas Pohlmeier (1), Petrik Galvosas (2), and Harry Vereecken (1)

(1) Agrosphere (IBG-3), Forschungszentrum Jülich GmbH, Jülich, Germany (m.duschl@fz-juelich.de), (2) School of Chemical and Physical Sciences, Victoria University of Wellington, Wellington, New Zealand

Nuclear Magnetic Resonance (NMR) relaxation and NMR diffusion measurements are two of a series of fast and non-invasive NMR applications widely used e.g. as well logging tools in petroleum exploration [1]. For experiments with water, NMR relaxation measures the relaxation behaviour of former excited water molecules, and NMR diffusion evaluates the self-diffusion of water. Applied in porous media, both relaxation and diffusion measurements depend on intrinsic properties of the media like pore size distribution, connectivity and tortuosity of the pores, and water saturation [2, 3]. Thus, NMR can be used to characterise the pore space of porous media not only in consolidated sediments but also in soil.

The physical principle behind is the relaxation of water molecules in an external magnetic field after excitation. In porous media water molecules in a surface layer of the pores relax faster than the molecules in bulk water because of interactions with the pore wall. Thus, the relaxation in smaller pores is generally faster than in bigger pores resulting in a relaxation time distribution for porous media with a range of pore sizes like soil [4]. In NMR diffusion experiments, there is an additional encoding of water molecules by application of a magnetic field gradient. Subsequent storage of the magnetization and decoding enables the determination of the mean square displacement and therefore of the self-diffusion of the water molecules [5]. Employing various relaxation and diffusion experiments, we get a measure of the surface to volume ratio of the pores and the tortuosity of the media.

In this work, we show the characterisation of a set of sand and soil samples covering a wide range of textural classes by NMR methods. Relaxation times were monitored by the Carr-Purcell-Meiboom-Gill sequence and analysed using inverse Laplace transformation. Apparent self-diffusion constants were detected by a 13-intervall pulse sequence and variation of the storage time. We correlated the results with various soil properties like texture, water retention parameters, and hydraulic conductivity. This way we show that we can predict soil properties by NMR measurements and that we are able use results of NMR measurements as a proxy without the need of direct measurements.

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