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Monitoring microbial growth and activity using spectral induced polarization and low-field nuclear magnetic resonance

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Microbes and microbial activities in the Earth's subsurface play a significant role in shaping subsurface environments and are involved in environmental applications such as remediation of contaminants in groundwater and oil fields biodegradation. Stimulated microbial growth in such applications could cause wide variety of changes of physical/chemical properties in the subsurface. It is critical to monitor and determine the fate and transportation of microorganisms in the subsurface during such applications. Recent geophysical studies demonstrate the potential of two innovative techniques, spectral induced polarization (SIP) and low-field nuclear magnetic resonance (NMR), for monitoring microbial growth and activities in porous media. The SIP measures complex dielectric properties of porous media at low frequencies of exciting electric field, and NMR studies the porous structure of geologic media and characterizes fluids subsurface. In this laboratory study, we examined both SIP and NMR responses from bacterial growth suspension as well as suspension mixed with silica sands. We focus on the direct contribution of microbes to the SIP and NMR signals in the absence of biofilm formation or biomineralization. We used *Zymomonas mobilis* and *Shewanella oneidensis* (MR-1) for SIP and NMR measurements, respectively. The SIP measurements were collected over the frequency range of 0.1 - 1 kHz on *Z. mobilis* growth suspension and suspension saturated sands at different cell densities. SIP data show two distinct peaks in imaginary conductivity spectra, and both imaginary and real conductivities increased as microbial density increased. NMR data were collected using both CPMG pulse sequence and D-T_2 mapping to determine the T_2-distribution and diffusion properties on *S. oneidensis* suspension, pellets (live and dead), and suspension mixed with silica sands. NMR data show a decrease in the T_2-distribution in *S. oneidensis* suspension saturated sands as microbial density increase. A clear distinction in the T_2-distribution and D-T_2 plots between live and dead cell pellets was also observed. These results will provide a basis for understanding the effect of microbes within geologic media on SIP and low-field NMR measurements. This research suggests that both SIP and NMR have the potential to monitor microbial growth and activities in the subsurface and could provide spatiotemporal variations in bacterial abundance in porous media.