Induced Polarization Signature of Biofilms in Porous Media: From Laboratory Experiments to Theoretical Developments and Validation

University-Led Research

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Our newly funded grant is focused on characterizing the major components and processes within bacterial biofilms contributing to detectable biogeophysical signals, spectral induced polarization (SIP) signatures in particular. Although the SIP technique has emerged as the technique most sensitive to the presence of microbial cells and biofilms in porous media, mechanistic aspects of the relationships between biological interactions with geologic media and the ensuing SIP response remain poorly understood largely because of competing effects of a myriad of contributing factors. Thus it is often difficult to unambiguously distinguish the impact of multiple and often competing processes that occur during in-situ biostimulation activities on the SIP signatures. Through geophysical laboratory column experiments, coupled with time-lapsed synchrotron based X-ray microtomography (CMT) and Scanning Confocal Laser Microscope (SCLM) analysis of biofilms we propose to: (i) evaluate the contribution of biofilm components to SIP signatures using field relevant organisms, (ii) determine the contribution of nanoparticulate biogenic minerals in biofilms to SIP signatures, (iii) determine if the SIP signatures can be used to quantify the rates of biofilm formation and biogenic mineral accumulation in subsurface media, (iv) develop a fundamental understanding of potential underlying polarization mechanisms at low frequencies (<40 kHz) resulting from the presence of microbial cells and biofilms, and (v) evaluate the use of reactive transport models to predict the geophysical response associated with the development of biofilms in field conditions.

Although we are still in the very early stages of our project, so far we have started by expanding the POLARIS model initially developed to model the induced polarization response of silicate materials to the modeling bacteria growth in porous media. Our model results suggest that the polarization of the electrical double layer coating the surface of bacteria increases the quadrature conductivity of the porous material. Thus the change in quadrature conductivity can be directly related to changes in the specific surface area of the bacteria and to the increase in cell density/population due to bacterial growth. We tested this new model using the experimental dataset of Davis et al. (2006) and found that the model is able to reproduce the magnitude of the polarization in the experimental dataset. We conclude that this new model allows us to quantitatively assess SIP signatures of bacterial growth in complex environments.

The next phase in our project is to evaluate the contribution of biofilm components to SIP signatures using field relevant organisms. We will begin by examining the effects of exopolymeric substances (EPS) and assess how the latter differs from the effect of high cell density.