A CASE STUDY on Low frequency spectral induced polarization Responses during bacterial growth and biofilm formation in sands under A high salinity condition

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Spectral induced polarization is one of the powerful geophysical monitoring techniques and it has been proposed for monitoring of bacterial activities in subsurface, such as bacterial growth, bioclogging, and metal reduction. However, the feasibility of spectral induced polarization method in highly saline environments, such as coastal and marine sediments, still remains unclear because the polarization response is suppressed by too high in-phase electrical conductivity. In this study, we present the spectral responses of complex conductivity of sand while the model bacteria, *Shewanella oneidensis* MR-1, are cultured and stimulated to form biofilms under a highly saline condition with ~2 S/m pore water conductivity. A column test was performed using the bacterium-stimulated sand pack while monitoring the complex conductivity in range of 0.01 Hz–10 kHz. The results reveal that the real conductivity rises in the early stage as a result of bacterial metabolites and surface conduction of the inoculated bacterial cells, while soon starts to drop after biofilm formation initiates pore clogging. In contrast, the imaginary conductivity shows a significant and gradual increase with time, displaying a clear bell-shaped relaxation spectrum with the peak frequency at 0.1–1 Hz. This phenomenon is attributed to the polarization of double layers bounded to biomasses such as bacterial cells, electrically conductive pili, and biofilms secreted by the model bacteria, named -polarization. The relaxation behavior is well captured using Cole-Cole relaxation model, which shows an increase in normalized chargeability and a decrease in relaxation time over time. Comparing to previous literatures performed under low-salinity condition, those trends confirm that the high-salinity condition suppresses the phase shift and thus the imaginary conductivity while it further increases the normalized chargeability. Our work suggests that the spectral induced polarization method is feasible to monitor subsurface bacterial activities in highly saline environments in spite of the suppressed polarization response.

*Keywords*: Spectral induced polarization, Complex electrical conductivity, *Shewanella oneidensis* MR-1, Cole-Cole relaxation model, High-salinity condition