Electrode-Based Approaches for Monitoring Microbial Activity and Carbon Cycling in Soils and Sediments

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There is a compelling need for strategies to simply and inexpensively monitor the activity of microorganisms in soils and sediments. This is true not only for the microbial monitoring that is required during subsurface bioremediation, but also for assessing changes in microbial activity due to environmental perturbations, such as climate change. Current methods typically involve invasive sampling of the environment, which can alter microbial activities, and require the addition of tracers or indicators, adding complexity and expense. Furthermore, these traditional methods are not amenable to real-time monitoring of *in situ* activity.

Our previous studies at the Integrated Field Research Challenge (IFRC) site in Rifle, CO demonstrated that microbially generated current was a good predictor of the amount of acetate reaching downgradient monitoring wells when acetate was added to the subsurface to promote uranium reduction. This monitoring system worked well even though the graphite anodes deployed in monitoring wells were connected to cathodes located 5 m away at the surface. Low levels of current were detected with anodes deployed in monitoring wells in control zones not amended with acetate, presumably due to microorganisms producing current from acetate, and possibly other electron donors, steadily produced over time from the natural degradation of complex organic matter in the subsurface.

Therefore, we hypothesized that it might be possible to monitor microbial activity in a diversity of anaerobic soils and sediments in real time based on the amount of current generated from anodes deployed in the environments of interest. Our primary goal for this project is to monitor microbial activity in unamended sites at Rifle to evaluate the relationship between indigenous rates of anaerobic microbial activity and the degree of uranium removal via the natural attenuation of microbial U(VI) reduction. Field experiments will be validated by laboratory studies using Rifle-derived microflora and natural organic matter concentrated from a variety of locations across the Rifle floodplain. However, as an initial proof-of-concept we evaluated current production versus rates of methane production in freshwater methanogenic sediments, because monitoring methane production in these sediments provided a simple independent means of estimating rates of carbon turnover under different conditions.

There was a strong correlation between rates of methane production in sediments and rates of current produced by electrodes emplaced in the sediments. Although the sediments were methanogenic, microorganisms in the family *Geobacteraceae* accounted for 69 % of the 16S rRNA gene sequences recovered from the anode surface. It is likely that the *Geobacteraceae* living on the electrode surface were utilizing acetate, and possibly other intermediates of anaerobic metabolism in the methanogenic sediments with electron transfer to the electrode. Thus, these results suggest that current production is likely to respond to changes in rates of carbon turnover in the same manner as natural terminal electron accepting processes. Therefore, it is expected that electrodes can provide an inexpensive noninvasive method for monitoring microbial activity and carbon cycling not only in groundwater, but also in a diversity of soils and sediments.