Seeing What a Microbe Sees: Real-Time Geochemical Monitoring with 'Geo-Sense'

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A limitation in biogeochemical modeling is a lack of real-time data on the *in situ* geochemical environment that directly impacts on microbial activity. Traditional analytical methods are often unable to distinguish speciation and/or complexation of molecules that have important influences on the interaction of those molecules with microbial enzymes. Furthermore, invasive sampling techniques, as well as the associated labor and analytical costs, prevent real-time analyses and limit the extent to which environmental heterogeneities and perturbations can be explored. We previously described SMART (Subsurface Microbial Activity in Real Time) technology, which provides real-time, continuous estimates of the overall rates of microbial activity in anaerobic soils and sediments. SMART takes advantage of the fact that the current-producing activity of microbes that colonize electrodes inserted into anaerobic soils reflects the activity of microbes in the nearby surrounding soil. In order to better understand the factors that control these rates of microbial activity, we are developing 'Geo-Sense' real-time biological sensors. Geo-Sense biosensors are designed to continuously report on the concentrations of important geochemical constituents that bacteria actually sense. The biosensors are constructed with strains of *Geobacter sulfurreducens* that specifically produce an electrical current in response to chemicals that interact with engineered genetic regulatory circuits. In this manner, the electrical response is to the biologically available fraction of nutrients or inhibitory compounds, providing a more microbiologically relevant analysis compared with bulk chemical analysis. Although biological sensors based on current-producing microorganisms have been described previously, those sensors relied on controlling the expression of proteins necessary for electron transfer to electrodes. This approach yields slow response times and lacks resolution. Geo-Sense biosensors utilize a different approach to control the current output. Proof-of-concept studies with either isopropyl ß-D-1-thiogalactopyranoside (IPTG) or anhydrotetracycline as the inducer yielded promising results and Geo-Sense strains have now been produced for the detection of iron, arsenic, or mercury. The Geo-Sense platform offers the potential for construction of a wide diversity of chemicals for which a microbial sensor system can be identified. To date Geo-Sense has only been tested in controlled laboratory conditions. However, a strategy for field deployment based on our previously patented microbial fuel cell technology has been developed. It is expected that coupling Geo-Sense and SMART technologies will make it feasible to inexpensively and remotely collect real-time data not only on rates of microbial activity but important geochemical parameters influencing microbial activity in a diversity of soils and sediments.