ABSTRACT: Strategies to simply and inexpensively monitor the activity of microorganisms in soils and sediments are needed for studies on bioremediation and 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.

We are developing a simple and inexpensive electrode-based method for monitoring rates of microbial activity in a wide diversity of anaerobic soils and sediments. Our strategy is based on the concept that the pathways for intermediary metabolism of organic carbon are similar in all anaerobic soils regardless of whether the terminal electron-accepting process is Fe(III) reduction, humics reduction, sulfate reduction, or methane production. In each type of soil, complex organic matter is fermented to simple intermediates, such as acetate and H₂, which are then consumed by the terminal respiratory processes. If a graphite electrode is inserted in anaerobic soil and connected to another electrode in contact with oxygen, then the electrode in the soil can serve as an alternative electron acceptor. Microorganisms colonizing the electrode surface will oxidize the acetate and other intermediates, produced from fermentation, with electron transfer to the electrode. The rate of this electron transfer is measurable as an electrical current. Thus, in the absence of any other complicating factors, it can be expected that the amount of current produced from an electrode in an anaerobic soil will be directly related to the rates of microbial metabolism in those soils or sediments.

This concept is being tested with a diversity soils and sediments in which different electron accepting processes predominate. Cores of freshwater methanogenic sediment were incubated at a range of temperatures to provide sediments with a range of rates of metabolism. Graphite electrodes were inserted at different depths in the sediments and electrically connected to graphite cathodes suspended in the overlying water through a resistor. Remarkably stable currents were recorded with higher currents at sediment depths or temperatures that were expected to have higher rates of microbial metabolism.

In order to directly compare current production with rates of microbial activity, the sediments near each electrode was sampled by subcoring and the subcores were injected with a [2-¹⁴C]-acetate tracer. Production of ¹⁴CH₄ and ¹⁴CO₂ were monitored over time to determine the rates of acetate metabolism in the sediments. There was a strong positive correlation between the rates of microbial metabolism determined with the traditional [2-¹⁴C]-acetate tracer techniques and the levels of current production. Similar studies were conducted on artic peat from the DOE Next-Generation Ecosystem Experiments (NGEE) Arctic project site in the Barrow Experimental Observatory near Barrow, Alaska. The correlation between rates of metabolism as determined with [2-¹⁴C]-acetate and current production fell on the same line as for the methanogenic sediments, despite the fact that in some of the artic peat sediments Fe(III) reduction appeared to be the predominant terminal electron-accepting process. Electrode deployments at the NGEE site generally yielded in situ currents consistent with the laboratory studies.