Thermodynamics controls the rates of microbial sulfate reduction

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Microbial sulfate reduction occurs widely in natural environments, playing an important role in global carbon and sulfur cycles. Predicting the rates of sulfate reduction is important in understanding how natural environments control microbial metabolisms and how sulfate reduction affects the chemistry of natural environments.

Sulfate can be reduced by oxidizing organic compounds though either an incomplete or a complete pathway. Organic matter oxidation and sulfate reduction release energy ΔE, part of which, denoted as ΔE_x, is conserved as either proton motive force or ATP. The other part constitutes the thermodynamic driving force f, i.e. $f = \Delta E - \Delta E_x$. The driving force f controls the rate r of sulfate reduction

$$r = r' \times F_T$$

where r' is the rate predicted by the rate laws (e.g. the dual-Monod equation) that neglect the thermodynamic control, and F_T is the thermodynamic potential factor,

$$F_T = 1 - \exp(f/(k_B T))$$

Here k_B is Boltzmann constant and T is absolute temperature.

The energy conserved (ΔE_x) can be determined from the value of ΔE where sulfate reduction stops and the driving force f decreases to zero. Taking *Desulfovbrio desulfricans* G20 and *Desulfobacter hydrogenophilus* as examples, the energy conserved is about 0.2V for the incomplete pathway and 0.05V for the complete pathway. The values of ΔE_x are independent of bacterial strains and experimental conditions.

The energy available ΔE is often small, even close to the value of ΔE_x, due to the small standard redox potential differences between organic matter oxidation and sulfate reduction. Therefore, the value of f is small and sulfate reduction rates are controlled significantly by the driving force. Kinetic experiments using both G20 and *D. hydrogenophilus* demonstrate strong thermodynamic controls on reaction rates.

In natural environments, microbial sulfate reduction encounters a special challenge because substrate concentrations are often small. As a result, the driving force is small, limiting sulfate reduction rates. Predicting the rates of sulfate reduction in natural environments therefore requires consideration of how the energy available controls the progress of sulfate reduction.

Unravelling the effects of macrofauna, macrophytes and microbes on iron and sulfate reduction in saltmarsh sediments

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Saltmarsh sediments host enormous geochemical and microbiological heterogeneity, both spatially and temporally. The intertwined geochemical and microbial processes occurring in such sediments influence each other, and are also shaped by the presence and activities of larger organisms. In particular, macrophyte roots and ventilated macrofaunal burrows create a variety of temporally-varient geochemical microzones and microbial habitats that promote unexpected seasonal oscillations in microbial iron and sulfate reduction.

Seasonal variations in anaerobic respiration pathways were investigated at three sites in a saltmarsh at Sapelo Island, GA using chemical data together with enumerations of culturable populations of Fe reducing bacteria (FeRB) and quantification of *in situ* 16S rRNA hybridization signals for sulfate-reducing bacteria (SRB); sulfate reduction rates (SRR) have been measured at the same sites and seasons [1]. These data demonstrate that SRR follow seasonal changes in temperature and primary productivity of the saltmarsh with the lowest rates in winter and the highest in summer. In contrast, FeRB populations dramatically decrease at all sites during summer. This decrease is hypothesized to occur because of the enormous increase in sulfide produced by SRR during summer.

To test this notion, a series of slurry incubation experiments at 10, 20 and 30°C were completed. In incubations containing unamended sediments or sediments with added acetate or lactate, increasing temperature lead to higher SRR, but decreased FeRB populations. When sediments were amended with molybdate to inhibit microbial sulfate reduction, the inverse dependence of FeRB populations on temperature disappeared. Thus, both laboratory and field observations support a complex, sulfide-mediated interdependence of microbial iron and sulfate reduction in these saltmarsh sediments.

Reference

[1] Kostka et al. 2002, *Biogeochem* **50**, 49-76