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Metabolic Flux and Sulfur Isotope Analysis of Photoelectron-induced Sulfate Reduction

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Sulfate-reducing microorganisms (SRMs) play a crucial role in global biogeochemical cycles by mediating sulfate reduction and metal sulfide precipitation. However, their metabolic activity in organic-depleted environments remains poorly understood. Recent studies demonstrate that SRMs, particularly *Desulfovibrio desulfuricans* G20, can utilize photoelectrons from semiconducting minerals such as sphalerite (ZnS) to drive sulfate reduction in the absence of organic carbon [1]. In this study, we investigate the metabolic flux and sulfur isotope fractionation associated with photoelectron-induced sulfate reduction to elucidate its implications for microbial metabolism and sulfur cycling. Batch experiments with biogenic and abiogenic ZnS nanoparticles under illumination revealed that biogenic ZnS promotes sulfate reduction by 1.6 times and ATP production by 3.1 times compared to abiogenic ZnS [2]. Transcriptomic and microbial photoelectrochemical analyses suggest that G20 cells extract photoelectrons via cytochromes, nanowires, and electron shuttles, enhancing intracellular electron transfer and sulfate reduction efficiency. Moreover, sulfur isotope analysis indicates a distinct isotopic signature associated with photoelectron-driven sulfate reduction. This suggests that photoelectron transfer from semiconducting minerals to SRMs may influence isotopic fractionation in natural settings, particularly in oligotrophic environments where organic substrates are scarce. Our findings highlight a previously unrecognized photoelectron-based metabolism that sustains microbial sulfate reduction under energy-limited conditions, with implications for sulfur isotope geochemistry and microbial adaptation in anoxic environments. Understanding the role of photoelectrons in microbial sulfate metabolism provides new perspectives on ancient sulfur cycling and offers potential applications in bioremediation and sustainable metal recovery.

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[2] Zhong C, Ren Y, Guo YY, Lu A, Liu J*, Photoelectron-Promoted Sulfate Reduction for Heavy Metal Removal without Organic Carbon Addition, Environmental Science & Technology, 2024, 58, 49, 21680–21691.