Biological Design Doctoral Defense

Operational designs, materials, and microbial communities enabling mining-influenced water treatment in lignocellulosic sulfate-reducing biochemical reactors

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Abstract

Mining-influenced water (MIW), an acidic stream containing sulfate and dissolved metal(loid)s, is among the most dangerous aqueous streams impacting freshwater ecosystems. Lignocellulosic sulfate-reducing biochemical reactors (SRBRs) are considered a cost-effective passive treatment for MIW and have been documented to continuously treat MIW at the field-scale. However, long-term operation (> 2 years) and reliable MIW treatment by SRBRs at mining sites is challenged by the decline in sulfate-reduction, the key treatment mechanism for metal(loid) immobilization.

This dissertation addresses operational designs and materials suited to promote sulfate reduction in lignocellulosic SRBRs treating MIW. I demonstrated that lignocellulosic SRBRs containing spent brewing grains and/or sugarcane bagasse can be acclimated in continuous mode at hydraulic retention times (HRTs) of 7-12 d while simultaneously removing 80 ± 20% – 91 ± 3% sulfate and > 98% metal(loid)s. Additionally, I showed that decreasing the HRT to 3 d further yields metal(loid) removal (97.5 ± 1.3 – 98.8 ± 0.9%). Next, I verified the utility of basic oxygen furnace slag to increase MIW pH (2.6 ± 0.2 to 5.0 ± 1.0) in a two-stage treatment involving a slag stage and an SRBR stage containing spent brewing grains or sugarcane bagasse. The two-treatment stage promoted the formation of a sulfate-reducing microbial community and removed 92 ± 15 - 94 ± 7% of total metal(loid)s. Subsequently, I revealed that Bacteroides, Fibrobacter, and Treponema emerge first as the dominating lignocellulolytic and fermentative taxa in while Ruminiclostridium and Hydrogenispora relative abundances ultimately dominate with SRBR operation length. Results from my work also demonstrate that an MIW chemical pretreatment decreases the relative abundances of possible sulfate-reducing bacteria competitors such as chain-elongators and methanogens. Finally, I applied my research to present a study aimed to uncover possible electron donor competitions among sulfate-reducing bacteria, chain-elongating bacteria, and methanogens in semi-batch studies replicating SRBR conditions. I also propose the possible application of lignocellulosic SRBRs to treat coal combustion residual leachate, a typically alkaline aqueous stream containing sulfate and metal(loid)s. Overall, my dissertation provides insight into materials and operational designs promoting long-term sulfate reduction in lignocellulosic SRBRs treating MIW.

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