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FIELD-PILOT BIOCHEMICAL PASSIVE REACTORS FOR TREATMENT OF ACID MINE DRAINAGE: PERFORMANCE AND MOLECULAR ECOLOGY ANALYSIS

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Coal mining has led to severe environmental issues, including acid mine drainage (AMD) production, which degrades aquatic habitats and soil quality. A sustainable remediation strategy is the use of biochemical passive reactors (BPRs), previously designed and tested under laboratory conditions. This study evaluated six field-pilot BPRs (220 L) treating AMD over 16 months, with the following composition: 1200 ± 91 mg L^{-1} Fe, 38.0 ± 1.3 mg L^{-1} Mn, 8.5 ± 1.0 mg L^{-1} Zn, and 3200 ± 183.8 mg L^{-1} SO_4^{2-} at pH 2.8. The BPRs operated under two configurations: open (BPRs-A) and closed (BPRs-B) to the atmosphere (Fig. 1). BPRs-A achieved removal rates of 74% for SO_4^{2-}, 63% for Fe^{2+}, and 48% for Mn^{2+}, while BPRs-B showed higher efficiencies, removing 91%, 80%, and 66%, respectively. Both configurations achieved 99% Zn^{2+} removal. These results, highlighting the impact of reactor configuration on AMD treatment performance.

One reactor from each configuration was sacrificed at 10 month, and post-treatment solid waste was sampled from bottom, middle, and top layers. Molecular ecology analysis using 16S rRNA sequencing revealed that bioremediation was driven by beneficial interactions within sulfate-reducing microbial communities. Differences in microbial composition between BPR configurations were primarily influenced by environmental conditions (Fig. 2).

Alpha diversity indices indicated a decline in species richness over time as specialized microbial communities were established. Beta diversity analysis (Weighted UniFrac) showed that microbial adaptation was influenced mainly by reactor type (open vs. closed). As well, functional profile results revealed that bioremediation effectiveness was driven by syntrophic interactions among hydrolytic, fermentative, and sulfate-reducing bacteria, consistent with laboratory-scale observations. However, community shifts altered specific taxa but preserved core operational dynamics. These findings confirm that reactor characteristics play a crucial role in optimizing AMD bioremediation in high-altitude ecosystems.

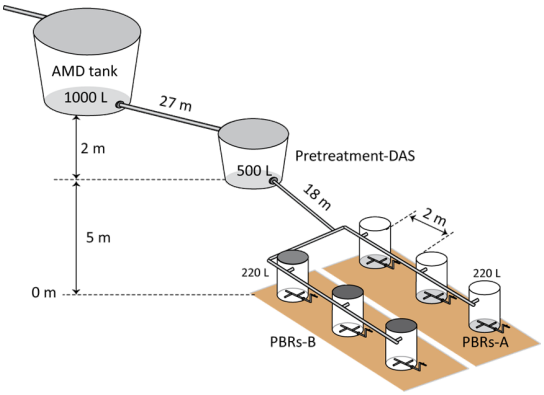

Fig. 1. Field-pilot passive biochemical reactors (PBRs) for AMD treatment, PBRs-A (open) and PBRs-B (Close) were both composed of three independent reactors.

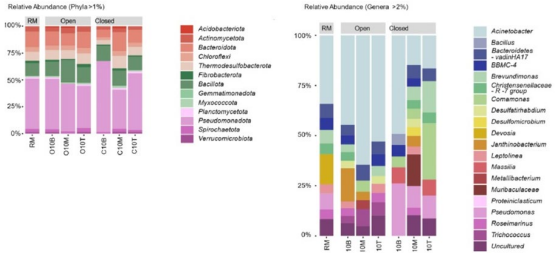

Fig. 2. Relative abundance of phyla and genera present in the BPRs after 10 months of operation, categorized by location (T = Top,M = Middle, B = Bottom layers) and configuration (O = Open, C = Closed).