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Impact of CO_2 concentration on biogeochemical weathering and acid mine drainage formation in abandoned mine areas

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Increasing atmospheric CO_2 levels may influence geochemical and microbial processes in abandoned mine environments, affecting both sulfide mineral weathering and acid mine drainage (AMD) formation. This study investigates how variations in CO_2 concentration impact the oxidation of sulfide minerals through biogeochemical pathways, as well as the role of carbonate buffering in regulating pH and AMD severity. The sulfur-oxidizing bacterium *Acidithiobacillus thiooxidans* is a chemolithoautotroph that atmospheric CO_2 consume as carbon source. The microbe plays a role in AMD formation by driving sulfide mineral weathering, which leads to the release of various heavy metals. The metabolic activity of *A. thiooxidans* is influenced by environmental CO_2 concentrations. Adequate CO_2 levels are essential for optimal growth and sulfur oxidation; however, both insufficient and excessive CO_2 availability can alter metabolic rates. In abandoned mining areas, *A. thiooxidans* contributes to the weathering of residual sulfide minerals, promoting sulfuric acid production, which further dissolves mineral matrices and releases trapped metals. This process is integral to AMD formation, characterized by low pH and elevated metal concentrations. Conversely, increased CO_2 levels can enhance sulfide mineral weathering and AMD generation, potentially accelerating the dispersion of heavy metals. On the other hand, CO_2 enrichment in water leads to the formation of carbonate species (e.g., HCO_3^- and CO_3^{2-}), which influence pH conditions. Carbonate species have a buffering capacity, consuming H^+ and stabilizing pH within a neutral range (6–8), rather than allowing the highly acidic conditions (<3) that *A. thiooxidans* prefers. This buffering effect could suppress *A. thiooxidans* activity despite increased CO_2 availability. Understanding the relationship between CO_2 concentrations and *A. thiooxidans* metabolic activity is crucial for developing strategies to manage and mitigate environmental impacts in mining areas under climate change.