Biogeochemistry of sulfide minerals oxidation at low temperatures

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Mesophilic iron/ sulfur-oxidizing microorganisms are widely distributed in environments such as acid mine drainage sites, but relatively little information is available about their activities at suboptimal temperatures and in cold environments. The objective of this study was to assess the oxidation rate of metal sulfide minerals at various temperatures. Oxidation rate of three different minerals (pyrite, galena, sphalerite) at temperatures of 4, 10 and 25^{O}C and pH 2 and 4 were tested with the *Acidithiobacillus thioxidans* strain. Experiments at 25^{O}C were carried out to compare of oxidation rates with lower temperatures. During the experiments, release of total iron (Fe_{tot}), lead (Pb), and zinc (Zn) were measured by ICP-MS along with sulfate concentration measurements with IC. The pH and redox potential (Pt electrode against an Ag0/AgCl reference) were also monitored. Mineral crystalline phases before and after oxidation were analyzed by powder X-ray diffraction (XRD). In general, the sphalerite and galena oxidation rates at 4, 10 and 25^{O}C were higher in the presence of A. *thiooxidans* than those in the chemical oxidation experiments. The higher oxidation rate for all minerals was obtained for 25^{O}C experiments. For sphalerite leaching at 25^{O}C at pH 4, SO_4 increased to 21.6 mM, pH dropped to 3.83 and Zn increased to 0.1 mM in 70 days. At pH 2, the respective values were 14.1 mM, 1.0 mM at the end of the biotic experiments, respectively. At 10^{O}C and pH 4, SO_4 was measured as 3.1 mM and Zn 0.01 mM at the end of the biotic experiment. At pH 2, the concentration of sulfate increased to 1.6 mM, the pH did not changed and zinc increased to 0.3 mM in biotic experiments (70 days). At 4°C and pH 4 oxidation of sphalerite by A. *thiooxidans* produced sulfate its concentration increasing to 2.7 mM, while pH dropped to 3.8 whereas at pH 2, the concentration of sulfate was 0.3 mM with insignificant pH change. Compared to 4^{O}C, higher levels of SO_4 and Pb at the end of leaching by A. *thiooxidans* at pH 2 and 4 were observed for galena at 10, 25^{O}C. In the presence of A. *thiooxidans* at 4, 10, and 25^{O}C, there was no significant pyrite oxidation throughout the entire experiment (82 days) as indicated by lower SO_4, Fetot concentration. XRD analysis especially from galena experiments showed various secondary mineral formation such as anglesite, polymorphite and elemental sulfur, which could control oxidation rate, at all temperatures. Our results have demonstrated that A. *thiooxidans* can survive at lower temperatures and the rate determining oxidation can be a specific mineral in addition to biochemical chemical reaction as indicated by various oxidation rates.

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