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Modeling pilot-scale passive treatment of manganese and zinc from a legacy mine in Japan

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Treating mine water with chemical-based active treatment is quite costly and not environmentally friendly. Thus, passive treatments are being considered globally as the alternative methods for mine water treatment. Passive treatment to remove manganese (Mn) and zinc (Zn) using manganese oxidizing bacteria has been implemented on a pilot scale (403-522 m^3/day) in Japan since 2021 [1]. The pilot-scale passive treatment effectively removed over 80% of Mn and Zn from the mine water at circumneutral pH (6.5-7.5), even though the factors that influence the rate of Mn and Zn removal from mine water are not fully known. In this study, we conducted a process model of the pilot-scale passive treatment to understand the kinetic effect on Mn and Zn removal from the mine water.

The geochemical model was created using PHREEQC and the WATEQ4F database. Mn and Zn concentrations from the pilot treatment were used for inverse modeling and model validation. PHREEQC was coupled with the PEST computer code to optimize the oxidation rate constant. The geochemical model suggests that birnessite was the primary mineral formed in the pilot treatment. Zn was removed from the mine water due to surface complexation with birnessite. Up to 90% of Zn was adsorbed onto birnessite at circumneutral pH, making the Zn removal rate dependent on birnessite. Birnessite formation was the rate-limiting factor in controlling Mn and Zn removal from the treatment plant. The Mn oxidation rate constant of the pilot-scale treatment in this study was four orders of magnitude smaller than the Mn oxidation rate constant of the passive treatment method found by Fuchida et al. (2020) [2]. The Mn oxidation rate constant depends on mineral surface area and bacterial concentration; however, bacteria had a higher influence on the oxidation rate. The Mn oxidation kinetic model indicated that at circumneutral pH, the oxidation rate of birnessite formation was mainly controlled by biological conditions.

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[2] Fuchida, S., Suzuki, K., Kato, T., Kadokura, M., Tokoro, C., (2020), Sci. Rep. 10, 20889.