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Seasonal Dynamics of Nickel Attenuation in Acid Mine Seepage: Implications for Remediation Strategies at BCL Copper-Nickel Mine Tailings, Botswana

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Abstract

Mining activities in Botswana have posed significant environmental challenges, notably acid mine drainage (AMD) resulting from sulfide ore processing at the BCL copper-nickel mine tailings. This generates AMD seepage characterized by low pH and high concentrations of dissolved toxic metals such as Fe, Ni, Cu, Pb, Zn, and Mn. The elevated concentration of heavy metals, particularly nickel, in the surrounding environment, groundwater, and nearby river underscores the challenge of remediating nickel contamination from tailings seepage. Thus, understanding nickel's behavior from acidic mine seepage is crucial for developing sustainable recovery and remediation strategies. The study aims to investigate the mechanisms controlling the natural attenuation processes of nickel from tailings seepage during rainy and dry seasons, informing geochemical passive treatment strategies. Objectives include determining the chemistry and behavior of toxic elements (Ni) from tailings seepage to the nearby river system in different seasons, understanding the release and mobility of toxic metals from the tailings, and elucidating the seasonal dynamics of nickel's natural attenuation from the tailings. Field surveys were conducted during both rainy and dry seasons, collecting tailings sediment, precipitate samples around the tailings, and sediment samples. Water samples were collected from the underground mine, tailings, and nearby river system. Heavy metal concentrations (Fe > Ni > Cu > Mn > Co > Pb > Ag > Cr) in the tailings seepage were notably high in both seasons, with higher values during the dry season. However, heavy metal concentrations exceeded the World Health Organization (WHO) and Botswana (BOBS) effluent standards in both seasons. In the dry season, heavy metal concentrations decreased post-treatment, except for nickel concentrations from the holding dam to the river, surpassing BOBS standards. Conversely, in the wet season, toxic metal concentrations, including nickel, fell below BOBS standards. Detailed analyses of tailing seepage, wastewater, river water, tailings sediments, precipitates, and river sediment furthered understanding of nickel's natural attenuation mechanism.

Keywords: Acid mine drainage; Tailings seepage; Nickel attenuation; Seasonal dynamic; Remediation strategies