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Effects of a reactive barrier and aquifer geology on metal distribution and mobility in a mine drainage impacted aquifer

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Abstract

The Nickel Rim aquifer has been impacted for five decades by a metal-rich plume generated from the Nickel Rim mine tailings impoundment. Metals released by the oxidation of pyrrhotite in the unsaturated zone of the tailings migrate into the downgradient aquifer, affecting both the groundwater and the aquifer solids. A reactive barrier has been installed in the aquifer to remove sulfate and metals from the groundwater. The effect of the reactive barrier on metal concentrations in the aquifer solids has not previously been studied. In this study, a series of selective extraction procedures was applied to cores of aquifer sediment, to ascertain the distribution of metals among various solid phases present in the aquifer. Extraction results were combined with groundwater chemistry, geochemical modelling and solid-phase microanalyses, to assess the potential mobility of metals under changing geochemical conditions. Reactions within the reactive barrier caused an increase in the solid-phase carbonate content downgradient from the barrier. The concentrations of poorly crystalline, oxidized phases of Mn and Fe, as well as concentrations of Cr(III) associated with oxidized Fe, and poorly crystalline Zn, are lower downgradient from the barrier, whereas total solid-phase metal concentrations remain constant. Iron and Mn accumulate as oxidized, easily extractable forms in a peat layer overlying the aquifer. Although these oxides may buffer reducing plumes, they

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also have the potential to release metals to the groundwater, should a reduced condition be imposed on the aquifer by remedial actions.

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1. Introduction

The release of dissolved metals from sulfide-mineral oxidation within mine wastes affects the water quality at mine sites worldwide. Sulfide-bearing mine tailings contribute significantly to the generation of acid and the release of metals to the environment. Acidic water generated by sulfide oxidation is neutralized by the dissolution of carbonate, (oxy)hydroxide and aluminosilicate minerals within tailings. As the pH increases, many metals precipitate or are adsorbed. The attenuation of metals occurs in tailings impoundments, and in aquifers, streams and lakes downgradient from impoundments (Morin et al., 1988; Blowes and Ptacek, 1994; Williams and Smith, 2000; Kimball et al., 2002).

Sulfide oxidation at some mine sites has generated acid for decades (Wood et al., 1999; Johnson et al., 2000; Moncur et al., 2003), as the buffering capacity of the mine wastes and adjoining aquifers has been exceeded. The depletion of the primary buffering capacity of the tailings and aquifer materials can result in the development of a plume of acidic, metal-bearing groundwater (Dubrovsky et al., 1985). As low-pH groundwater moves through the aquifer and tailings, it may re-dissolve metals that precipitated previously (e.g., Bain et al., 2001). Flooding or the addition of organic carbon covers to tailings impoundments is employed as means of preventing sulfide oxidation and the generation of acid. When applied to oxidized tailings, flooding or the addition of organic carbon may induce reducing conditions in the tailings resulting in the potential for the release of metals by reductive dissolution (Ribet et al., 1995). To assess the potential impact of mine wastes on surrounding waters over several decades or even a century, and to evaluate the potential effects of mitigative measures, it is necessary to understand the distribution and binding of metals in tailings and aquifers.

Most studies of the impact of mine drainage on the Nickel Rim tailings and aquifer have focused on pore water quality (Bain et al., 2000; Benner et al., 2000; Johnson et al., 2000), with the exception of Ribet et al. (1995) who studied the solid-phase geochemistry of the oxidized tailings. Less information, however, is available with respect to the solid-phase composition of the Nickel Rim aquifer. The purpose of this study was to determine the effects of a reactive barrier and aquifer geology on the solid-phase geochemistry of the aquifer, using solid-phase extraction techniques. Based on the groundwater chemistry and the solid-phase chemistry, inferences are made with respect to solid-phase controls on metal mobility, the potential for future metal release, and redox and pH buffering capacity. Geochemical modelling is used to enhance the understanding of the effects of a reactive barrier installed in the aquifer in 1995 and of the aquifer geology, on the solid-phase chemistry and on metal mobility.

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