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Water quality impacts and river system recovery following the 2014 Mount Polley mine tailings dam spill, British Columbia, Canada

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ABSTRACT

The Mount Polley mine tailings embankment breach on August 4th, 2014, in British Columbia, Canada, is the second largest mine waste spill on record. The mine operator responded swiftly by removing significant quantities of tailings from the primary receiving watercourse, stabilizing the river corridor and beginning construction of a new river channel. This presented a unique opportunity to study spatial patterns of element cycling in a partially-restored and alkaline river system. Overall, water quality impacts are considered low with Cu, and to a lesser extent V, being the only elements of concern. However, the spatial pattern of stream Cu loading suggested chemical (dominant at low flow) and physical (dominant at high flow) mobilization processes operating in different parts of the watershed. Chemical mobilization was hypothesized to be due to Cu sulfide (chalcopyrite) oxidation in riparian tailings and reductive dissolution of Cu-bearing Fe oxides in tailings and streambed sediments whereas physical mobilization was due to erosion and suspension of Cu-rich stream sediments further downstream. Although elevated aqueous Cu was evident in Hazeltine Creek, this is considered a relatively minor perturbation to a watershed with naturally elevated stream Cu concentrations. The alkaline nature of the tailings and the receiving watercourse ensures most aqueous Cu is rapidly complexed with dissolved organic matter or precipitates as secondary mineral phases. Our data highlights how swift removal of spilled tailings and river corridor stabilization can limit chemical impacts in affected watersheds but also how chemical mobilization (of Cu) can still occur when the spilled tailings and the receiving environment are alkaline. We present a conceptual model of Cu cycling in the Hazeltine Creek watershed.

1. Introduction

On August 4th, 2014, a partial embankment breach of the Mount Polley tailings storage facility (TSF) in British Columbia, Canada, led to the release of approximately 25 Mm^3 of mine tailings and supernatant water into the Quesnel River Watershed (WISE, 2016; Petticrew et al., 2015). The embankment breached due to a geotechnical failure of a layer of glacio-lacustrine clay in the foundation materials below the dam (Independent Expert Engineering Investigation and Review Panel, 2015). The Mount Polley event was significant for four reasons. First, at the time of the accident it was the largest ever documented spill of mine tailings into the environment (WISE, 2016). Second, among tailings spills, the Mount Polley accident was unusual in that the tailings are not acid-generating and contain generally low levels of trace metals and metalloids when compared to typical tailings (Golder Associates Ltd, 2015; Kossoff et al., 2014). Third, the environmental clean-up operations were swift; within one year of the event a significant volume of the spilled tailings had been removed from the major receiving watercourse and an extensive river restoration scheme was under construction (Independent Expert Engineering Investigation and Review Panel, 2015). Fourth, the Mount Polley spill highlighted the increasing global environmental risk of such events, due to the growing number of

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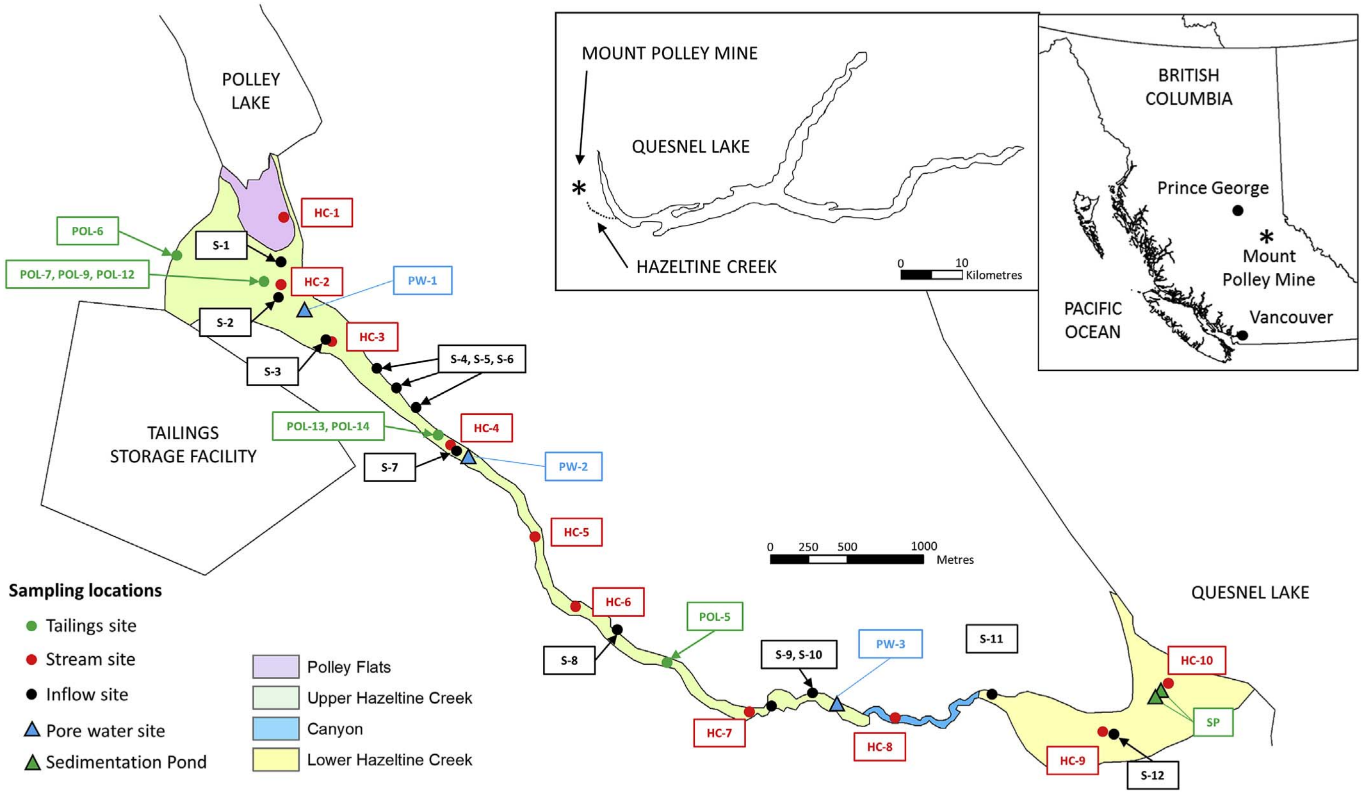

Fig. 1. Location of study area showing tailings, stream (streamflow and water quality) and inflow (water quality only) sample sites.

mining operations and higher waste to ore ratios, and due to the growing vulnerability of these types of environments to extreme hydrometeorological events (Hudson-Edwards, 2016).

Following the embankment breach, tailings material initially discharged north into Polley Lake before forming a 'plug' (area known as Polley Flats in Fig. 1) that blocked water flowing from Polley Lake. The tailings material subsequently flowed south-east into Hazeltine Creek and then discharged into the West Basin of Quesnel Lake. The tailings material initially eroded the existing valley, both vertically and laterally (SNC-Lavalin Inc, 2015). Subsequently, thick deposits of tailings (up to 3.5 m thick) occurred primarily near Polley Lake and in Lower Hazeltine Creek with thinner layers occurring in other parts of the creek. Tailings were deposited within the riparian zone up to 100 m from Hazeltine Creek.

The ore body at Mount Polley is a typical alkalic porphyry Cu-Au deposit with supergene enrichment (McMillan, 1996). The dominant ore mineral is chalcopyrite ($CuFeS_2$), but Cu also occurs as other sulfide (bornite – Cu_5FeS_4, covellite – CuS, digenite – Cu_9S_5), silicate (chrysocolla – $(Cu,Al)_2H_2Si_2O_5(OH)_4.nH_2O$) and carbonate hydroxide minerals (malachite – $Cu_2CO_3(OH)_2$) (Henry, 2009). Importantly, the ore has a low sulfide (0.1–0.3 wt. %) and high calcite (5–10 wt. %) content giving it a high neutralization potential. Tailings generated from the processing of Mount Polley ore also have generally low metal concentrations (mg kg^{-1}: As, 8–13; Cd, 0.1–0.3; Cr, 8–55; Cu, 65–1475; Pb, 4–12; Hg, < 0.1–0.3; Ni, 6–36.4; Se, 0.3–1.9; V, 86–295; Zn, 40–82) (SRK Consulting (Canada) Inc, 2015c) when compared to other spilled tailings (Bird et al., 2008; Hudson-Edwards et al., 2003).

Evidence from water sampling surveys carried out in Hazeltine Creek shortly after the breach revealed elevated above British Columbia Water Quality Guidelines – BCWQG (British Columbia Ministry of Environment (BCMoE), 2017)) filtered concentrations of several metals including Cu (maximum: 86 μg L^{-1}) and Se (maximum 33 μg L^{-1}) that have decreased substantially since the event (Golder Associates Ltd, 2015). Following the breach, Mount Polley Mining Corporation implemented an on-going rehabilitation and remediation strategy that has involved removing tailings from Lower and Upper Hazeltine Creek and construction of a new rock-lined channel and fish habitat (MPMC, 2015). Early evidence from geochemical investigations (humidity cell and column tests) suggests Cu has limited environmental mobility (predicted maximum Cu concentration of 20 μg L^{-1}) due to the low acid generating potential of the tailings (SRK Consulting (Canada) Inc, 2015c). Overall, this result suggests the tailings may be relatively non-reactive, thereby limiting the potential long-term chemical impacts of the spill. However, column tests, while very useful, cannot entirely replicate environmental conditions in complex field sites, especially at the interface between deposited tailings and the river corridor, where temperature, daylight, microbial activity, redox potential, pH and hydrology are constantly changing. Watershed-scale investigations of trace metal dynamics are therefore required to supplement existing laboratory-based microcosm data and to determine the environmental risk of residual tailings in the stream corridor.

The Mount Polley tailings spill presents a unique opportunity to study water quality impacts and water-sediment interactions in a receiving watercourse whose valley morphology was re-set by the spill event and whose channel has subsequently been modified and realigned. Since the event, there have been several environmental impact studies conducted by consultants on behalf of Mount Polley Mining Corporation (Golder Associates Ltd, 2015; Minnow Environmental Inc, 2015; SNC-Lavalin Inc, 2015; SRK Consulting (Canada) Inc, 2015a, b). The initial impacts of the spill on Quesnel Lake have also been documented (Petticrew et al., 2015). However, this work represents the first peer-reviewed study of the chemical impacts of the tailings spill on the primary receiving watercourse. Our specific objectives were to: (1) establish the spatial pattern and sources of element loading (specifically Cu) in Hazeltine Creek and (2) assess the potential for residual alkaline tailings in a partially-restored river corridor to influence short-to long-term aqueous chemistry.