Seasonal Geochemical Dynamics within an acid impacted tailings lake

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Abstract

One of the key concerns at the Falconbridge mine site (Sudbury, Ontario) is the generation of acidity in the tailings treatment pond, Moose Lake. Since Moose Lake discharges offsite through the Onaping River, there is concern about water quality of the Moose Lake effluent. The oxidation of sulfur is thought to be the major process generating excess acidity in this system, as sulfur oxidation intermediates (loosely termed thiosalts) have been detected. This process can proceed abiotically or biotically, though reaction rates are thought to be faster when bacterially catalyzed (Jorgensen, 1990; Schippers and Sand, 1999). Moose Lake is highly acidic (pH below 3.5), metal impacted, and chemically stratified. These characteristics likely provide the prerequisites for a microbial sulfur loop to exist (Del Don et al., 2001; Overmann et al., 1996; Tonolla et al., 2000).

To investigate the potential influence of microbial processes on acid generation, as well as characterizing any attendant influences for metal behaviour, the biogeochemistry of Moose Lake was characterized on a seasonal and a diel basis during the summer of 2002. Physico-chemical profiles obtained with a Hydrolab Surveyor 4A (Hydrolab Corporation) were used to identify the area of strong redox gradient across the chemocline (typically ~1 – 2 meters across this zone) on each sampling day. Samples at five depths within this redox gradient were then collected for Fe^{3+}/Fe^{2+}, $SO_4^{2-}/\sum H_2S$, metal and microbial samples, in addition to more highly resolved Hydrolab profiling. Samples were collected both during the lighted portion of the day (10am-12pm) and at dusk (6-8pm) to evaluate any contributions attributed to photosynthetic activity to S and/or Fe cycling.

Results indicate a clear seasonal increase in acidity in the upper waters of the lake. pH values dropped from 3.19 in May to 2.90 in September (Fig.1, e.g. a doubling of proton concentration from 580.44 µM to1248.11 µM). Further, a strong diel trend of increasing acidity (lower pH) from mid morning to dusk was also observed for each sampling period. This generation of acidity during the day correlated to observed S^{2-}/SO_4^{2-} and Fe^{2+}/Fe^{3+} dynamics consistent with sulfur oxidation processes, likely associated with microbial activity. Depth dependent variation in pH fluctuation, as well as Fe and S speciation, occurred across the redoxcline indicating that zonation of microbial processes is likely within this zone. Preliminary mass balance calculations indicate that at some shallower depths, the diurnal increase in proton concentration can be accounted for by abiotic oxidation of pyrrhotite, which has implications for tailings slurry disposal at the site. At deeper depths within the redox active zone however, abiotic processes alone cannot account for the observed concentration of protons generated. Biotically-mediated sulfur oxidation likely accounts for this increase. Microbial samples have revealed both concentrated and varied microconsortia across the redox gradient provided by the chemocline of Moose Lake. These communities are currently under investigation.

In summary, results from the 2002 field season revealed strong diel, and seasonal, trends of pH decreases in Moose Lake associated with sulfur oxidation as revealed by S^{2-}/SO_4^{2-} and Fe^{2+}/Fe^{3+} dynamics. These processes involving transformation of S and Fe are also likely to impact, in addition to system geochemical conditions, metal behavior (e.g. Cu). While some of these dynamics can be mapped at certain depths of this geochemical gradient to abiotic sulfur oxidation processes, at others the involvement of microbial communities is required to account for the diel decrease in pH. Ongoing work focuses on the characterization of the microbes at specific depths within the redox zone.

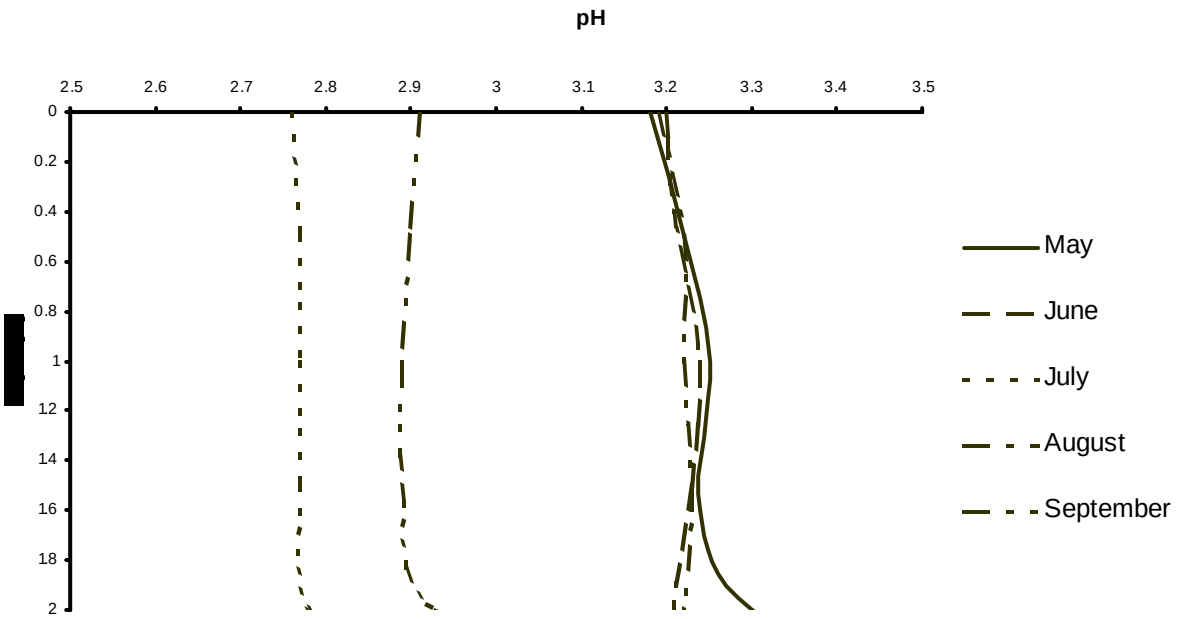

Fig.1 Seasonal pH variations from May to September 2002, in the upper two meters of Moose Lake, above the chemocline, Onaping, Ontario.

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