Geophysical Research Abstracts
Vol. 19, EGU2017-17912, 2017
EGU General Assembly 2017

Controls on the distribution of arsenic in lake sediments impacted by ∼65 years of gold ore processing in subarctic Canada: the role of organic matter

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Gold mines in the Yellowknife region of the Northwest Territories, Canada, operated from 1938 to 2003 and released approximately 20,000 tonnes of arsenic trioxide to the environment through stack emissions. This release resulted in highly elevated arsenic concentrations in lake surface waters and sediments relative to Canadian drinking water standards and guidelines for the protection of aquatic life. High northern latitudes are experiencing substantial impacts, including changes in bio-physico-chemical processes, due to climate change. Determining the affect of warming climate on contamination is complicated by the fact that little is known of climate change controls on As mobility and bioavailability. Further, while the role of dissolved organic matter in As cycling is relatively well characterized in soils and wetland sediments, few studies have investigated the role of solid organic matter in lacustrine systems. We use a meta-analytical approach to better understand controls on sedimentary arsenic distribution in lakes within a 50 km2 area of historic mineral processing activities. Arsenic concentrations in near surface sediments of the 100 lakes studied range from 5 mg/kg to over 10,000 mg/kg (median 81 mg/kg). Distance from the historical Giant Mine roaster stack and the amount of labile organic matter (S1 carbon as determined by Rock Eval pyrolysis) in lake sediments are the variables most strongly correlated with sedimentary As concentrations (Spearman's rank correlation As:distance from historic roaster rs=-0.57, $p<0.05$; As:S1 rs=0.55, $p<0.05$). The S1 fraction, volatile hydrocarbons derived from readily degradable geolipids and pigments predominantly originating from authochthonous organic matter, represents a small portion of the overall total organic carbon in the sedimentary material analyzed (median 2.33 wt.%). However, this fraction of organic matter has large potential to influence element concentrations in lake sediments through coating of pre-existing solid-phase As-mineral complexes, direct As-organic matter interactions, and promotion of microbial-mediated reduction and precipitation of As-bearing minerals.