Metal contaminant emissions to waters surrounding a large tailings pond: Athabasca Oil Sands, Alberta.

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Reactive Transport Model

Alberta Oil Sands mining has introduced intensive petrochemical processing into an environmentally sensitive boreal landscape. The resulting tailings ponds are considered an environmental risk for contaminant emissions to surrounding environments. A reactive transport model has been developed along two transects of wells in order to quantify the fluxes of metal and organic contaminant emissions from a large tailings pond into surrounding ground and surface waters, including the Athabasca River. Here we report the results of the inorganic portion of that study, including lead and zinc isotopic signatures as a method for discriminating natural from anthropogenic contaminant emissions.

Metal concentrations in both ground and surface waters surrounding the tailings pond are lower than current environmental guidelines. Dissolved metal contaminant concentrations demonstrate a strong attenuation profile down gradient from the tailings pond. PHREEQC modelling, SEM observations, and precipitate monitoring all indicate groundwaters are strongly supersaturated in iron and manganese oxyhydroxides throughout the well profiles. Sorption of metals by actively precipiting oxyhydroxides can account for the subsurface attenuation profiles. Modelling suggests that the rate of subsurface metal sequestration along the groundwater flow path are ~10 µg/L Zn, ~0.5 µg/L As; ~1 µg/L Pb; ~20 µg/L Ni. These are calculated from a temporally limited suite of samples that may not represent long-term averages.

The metal isotopic dataset is from Athabasca River water, McMurray Formation, and groundwaters downflow of the active area of metal sequestration. The data fall on a mixing line between Athabasca River and McMurray Formation end-member signatures, suggesting that this technique has significant potential for discriminating natural from anthropogenic sources. However, there is minor scatter in the groundwater data that suggests further research is required to better characterise other potential end-member isotopic signatures (e.g. Clearwater and Waterways formations).

Conclusions

The flux of metal contaminants from the tailings pond reaching the Athabasca River is low due to the active sequestration process. Hydrogeological modelling to be completed shortly will determine the flux of subsurface metal sequestration, and will help assess the utility of metal isotopic analyses for monitoring metal contaminant emissions in this area.

Stable isotopes reveal biogeochemical processes in a shallow, eutrophic lake

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Recent research has shown how the isotopic compositions of dissolved inorganic carbon (δ^{13}C-DIC) and dissolved oxygen (δ^{18}O-DO) can be used to track biogeochemical processes in rivers [1] and shallow groundwater [2]. This study uses the same approach to examine processes occurring under ice cover in Georgetown Lake, a shallow, eutrophic lake in western Montana, USA. The results have implications for survival of fish during winter hypoxia.

After the onset of ice (Nov-2010), DO concentrations decreased sharply with depth and time at two monitoring sites, while δ^{18}O-DO increased (Fig. 1B, Trends III, IV). Conversely, DIC concentrations increased with depth and time, while δ^{13}C-DIC initially decreased (Fig. 1A, Trend I). These trends are consistent with a respiration: photosynthesis ratio > 1. The lower slope of Trend IV vs. Trend III indicates a higher rate of photosynthesis (which produces isotopically light DO) at Site 2, which partly counteracts the effects of respiration (which preferentially consumes light DO). Photosynthesis in the top 1-2 m of the water column provides enough DO for trout and land-locked salmon to survive the 6-month winter.

Late in the winter, the deeper waters at both sampling sites (especially Site 2) saw a continued increase in DIC concentration and an increase in δ^{13}C-DIC (Fig. 1A, Trend II). Trend II is best explained by a shift in the dominant microbial pathway in the deeper water column and underlying sediment from organic-C oxidation to organic-C disproportionation, the latter yielding a mixture of isotopically heavy CO_2 and isotopically-light CH_4 [3]. Work is in progress to measure CH_4 and dissolved organic carbon concentrations and isotopic compositions to confirm this hypothesis.

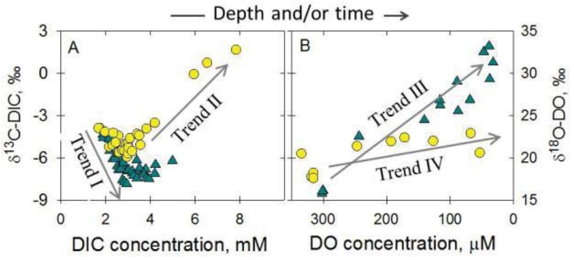

Figure 1: Seasonal changes in the concentration and isotopic compositions of (A) DIC and (B) DO between Nov-2010 and May-2011. Triangles are Site 1 (max. depth = 9 m); circles are Site 2 (max. depth = 6 m). Depth in the water column and elapsed time increase from left to right in both diagrams.

[1] Parker *et al.* (2010) *Chem. Geol.* **269,** 22-32. [2] Smith *et al.* (2012) *Geochim. Cosmochim. Acta* **75**. 5971-5986. [3] Whiticar (1999) *Chem. Geol*. **161**, 291-314.