In-situ reduction reduction of greenhouse gases from the Athabasca oil sands tailings ponds: detailed insights using ultrahigh resolution mass spectrometry

Host University:
University of Warwick

Theme:
Climate & Environmental Sustainability

Supervisory team:
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Project Highlights:
- State-of-the-art mass spectrometry instrumentation (amongst world-leading)
- International environmental research
- Supervisory team consists of world leaders in oil sands, soil microbial profiling, and complex mixture analysis

Overview:
Canada has the world’s third largest oil reserves, due to the exploitation of the Athabasca oil sands in Alberta, Canada. The oil sands represents an alternative source of petroleum which consist of clay, sand, water, and bitumen, where the bitumen can be extracted using an alkaline hot water extraction process. Approximately three barrels of water are needed to produce one barrel of oil but this water, oil sands process affected water (OSPW), cannot be discharged back into the environment, due to federal regulations. This OSPW must be stored in vast tailings ponds and contains compounds that are known to be toxic in aquatic environments. In addition to anthropogenic effects upon the aquatic environment, there are concerns relating to greenhouse gases (GHG) and climate change.

The presence of inorganic and organic contaminants (metals, salts, petroleum hydrocarbons, naphthenic acids, etc.), emission of biogenic GHG (CH₄ and CO₂), and slow consolidation of fine tailings solids are all oil sands related challenges. Biogenic methane emissions from Mildred Lake Settling Basin alone have been estimated at 43,000 m³/day. As methane is approximately 25 - 30 times more potent as a GHG than CO₂, reducing CH₄ emission from tailings ponds would have a significant impact on lowering overall emissions from an oil sands mining operation.

For the treatment of mature fine tailings from tailings ponds, an approach is being explored which is already used in the agriculture, based upon usage of nitrates and phosphates. The student will collaborate with Environment and Climate Change Canada (ECCC) and NRCan CanmetENERGY Devon
in developing methods for the analysis of the soluble organic compounds before and after the mature fine tailings treatment. Fourier transform ion cyclotron resonance (FTICR) mass spectrometry (MS) is at the forefront of the molecular characterization of complex environmental samples, leading to generation of “profiles” or “fingerprints,” which can be used to facilitate understanding of the wastewater chemistry from an unconventional oil and gas industry. By applying state-of-the-art analytical methods to understand changes at the molecular level, the aim is to link this understanding to GHG reduction.

![Athabasca oil sands industrial facility, north of Fort McMurray (Alberta, Canada).](image)

**Figure 1:** Athabasca oil sands industrial facility, north of Fort McMurray (Alberta, Canada).

**Methodology:**

Nitrates and phosphates have the potential to reduce methane production from methanogenesis. This was initially interpreted as a consequence of nitrate and phosphate raising the redox potential of the medium, while subsequent studies have demonstrated that uptake of hydrogen by nitrate is thermodynamically favourable compared to uptake by CO$_2$, thereby inhibiting methanogenesis. Other compounds or their metabolites have also been identified as potential inhibitors of methane production, including sulfate, propionate precursors such as fumarate and acrylate, or copper. The project will use FTICR MS to “fingerprint” OSPW before and after different treatments. Ultrahigh resolution is required for detailed characterization of complex samples, with small mass differences such as 3.4 mDa resulting from O$_x$- and SO$_x$-containing compounds. By developing the treatment methods in the laboratory using OSPW, FTICR MS will be used to gain greater insights into the processes and effectiveness, as a means to furthering a strategy for GHG reduction.

**Training and skills:**
Students will be awarded CENTA2 Training Credits (CTCs) for participation in CENTA2-provided and ‘free choice’ external training. One CTC equates to 1⁄2 day session and students must accrue 100 CTCs across the three years of their PhD.

The student will gain training and expertise in the field of environmental analysis, including sample collection and preparation. The student will have the option to work in-house in Saskatoon, Canada, with the research team of Dr Headley. This international exposure will provide hands-on training in oil sands environmental chemistry. At the University of Warwick, the student will gain expertise from one of the world’s leading FTICR laboratories, learning FTICR mass spectrometry and including use of different ionization, fragmentation, and data analysis techniques.

**Partners and collaboration:**

Dr. Barrow has approximately 19 years of experience of working with FTICR mass spectrometry, petroleum-related samples, environmental samples, and data analysis and visualization of complex mixtures, collaborating with industry and with environmental organizations. Prof. Bending will provide expertise on microbial profiling, metagenomics, and soil microcosm type systems. Dr. Headley has approximately 41 years of research experience and is amongst the world’s leading experts on the oil sands industry, with more than 28 years of working at Environment and Climate Change Canada.

**Possible timeline:**

**Year 1:** Introduction to principles of FTICR mass spectrometry, training on the 12 T solariX at the University of Warwick, introduction to data analysis methods, analysis of initial samples

**Year 2:** Intent to coordinate field sampling with collaborators (NRCan CanmetENERGY Devon) for treated tailings from Canada.

**Year 3:** Focus of the work will be Athabasca oil sands region.

**Further reading:**


**Further details:**

For further information, please contact Dr. Barrow, Prof. Bending, or Dr. Headley directly:

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