ecoENERGY Innovation Initiative
Research and Development Component

Public Final Report

Project: UOSE 015
Dewatering Wet Tailings Generated from Oil Sands Extraction

July 23, 2016

1. **R&D gaps in dewatering wet tailings generated from Alberta oil sands**

Bitumen extraction from surface minable Alberta oil sands using the Clark Hot Water Extraction Process (CHWE) consumes significant amounts of fresh water and generates large amounts of unconsolidated wet tailings. On average, to produce one barrel of bitumen, 4-6 barrels of fresh water is required, and 12-15 barrels of tailings wastes are generated. While the majority of the tailings settle quickly allowing much of the contained process water to be recycled, about 1.6 barrels of the tailings form Mature Fine Tailings (MFT), which consist of residual bitumen, fine clays and water, take years to settle, and trap some of the process water, which cannot be recycled. The growing volume of the MFT, which is difficult to dewater, is a major environmental liability. The tailings ponds are hazardous to migratory birds and there are concerns about seepage of process affected tailings water into the Athabasca River. Oil sands production to date has accumulated 650 million cubic meters of MFT that requires management and reclamation.

Numerous studies have been conducted to solve the tailings dewatering and consolidation problem. The studies reported in open literature in the past five years include the addition of polymers flocculants (substances with high molar masses composed of a large number of repeating units), polymer flocculants coupled with metal cations, the use of bacteriophage (a virus that infects and replicates within bacteria), freeze-thaw cycles, filtration following flocculation, and centrifugation. The oil sands industry has also been using the consolidated tailings (CT) process in which coarse sands and gypsum are added to MFT to speed up water release. However, despite the efforts, there still exist major problems and knowledge-technology gaps, including but not limited to:

(1) High costs of polymer flocculants. The oil sands tailings are found to require one to two orders of magnitude higher polymer dosages to dewater compared to the typical mine tailings. While the mine tailings can be dewatered with much less than 100 g/t flocculant, the oil sands tailings require greater than 1 kg/t flocculants. Coupled with the large volumes of the oil sands tailings, the cost of the polymer flocculants is significant.
(2) Loose sludge caused by polymer flocculants. Although tested polymer flocculants cause fast settling of the tailings solids, they make the settled sludge more difficult to consolidate into high density sediments.
(3) The presence of residual organics/bitumen in the oil sands tailings affects the efficiency of many of the polymer flocculants and is one of the reasons for the need for high dosages of polymers.
(4) A lack of suitable and economical ways for post treatment of flocculated oil sands tailings.
(5) A lack of understanding of polymer/clay and polymer/oil sands interactions.

The project was carried out with the objective to address the knowledge/technology gaps associated with the slow dewatering and slow consolidation of the oil sands extraction tailings. This was the first project in which a holistic approach was taken to address both the fundamental and the practical aspects of the oil sands flocculation and dewatering.

## 2. Project initiation and evolution

The Institute for Oil Sands Innovation (IOSI) at the University of Alberta has been actively engaged in oil sands tailings processes studies since 2011. Five projects within IOSI: COSI 2012-01, COSI 2012-02, COSI 2012-03, COSI 2012-04, COSI 2012-05, were assembled into a R&D project application to Natural Resources Canada (NRCan), in the ecoENERGY Innovation Initiative, under the Unconventional Oil and Gas category. The project was awarded in March 2013, given a project number ecoEII UOSE 015, and was executed between April 2013 and March 2016 by IOSI at the University of Alberta. Imperial Oil Limited was the industrial partner of the project, who provided cash support to cover 25% of the direct costs of the project as well as in-kind support through sample collection and shipment and project consultation and stewardship.

The project had eight principal investigators (PIs) in charge of the different phases, and they were Jos Derksen (Technical University of Delft, The Netherlands), Julian Zhu and Suzanne Giasson (the University of Montreal), Xiaoli Tan, Qi Liu, Sean Sanders and Murray Gray (the University of Alberta), and Keng Chou (the University of British Columbia). Qi Liu acted as project coordinator on behalf of IOSI.

Under the project title “Dewatering Wet Tailings Generated from Oil Sands Extraction”, the research was to address the challenge of the volume reduction of the wet tailings generated from the current commercial hot-water extraction process. The project was divided into six phases which, when combined, represented a holistic approach to the fundamental aspects of the flocculation and dewatering of the tailings. The six phases were: modeling polymer-solids mixing in slurry (Jos Derksen); design and synthesis of novel amphiphilic polymer flocculants (Julian Zhu and Suzanne Giasson); use of commercial polymers of different molecular weights and ionic characters (Xiaoli Tan and Qi Liu); post-flocculation deposition (Sean Sanders) and filtration (Xiaoli Tan and Qi Liu); and polymer/mineral interactions (Keng Chou and Murray Gray).

## 3. Project objective

The objective of this Project is to use commercial polymers of different molecular weights and ionic characters and synthesize novel amphiphilic polymers, develop optimum polymer/oil sands tailings mixing processes, and exploit new deposition/filtration techniques for the polymer-flocculated oil sands tailings, to achieve fast oil sands tailings settling and accelerated dewatering of the settled oil sands sludge. The proposed research will provide technological solutions to assist in the effort to solve the problems associated with oil sands tailings dewatering, consolidation, impoundment and reclamation.

The proposed project will lead to the development of pre-prototype polymers and technologies. The intermediate outcome will formulate the best “reactors” for optimum mode of mixing polymer solutions with oil sands tailings resulting in maximum flocculation at the lowest polymer dosage, along with the development of suitable amphiphilic (hydrophobic-hydrophilic) copolymers, and/or cationic/anionic/non-ionic commercial polymers, for fast water release either by slope multi-lift deposition or by vacuum or pressure filtration.

## 4. R&D activities performed

The major R&D activities of this project include the computer simulation of the mixing and aggregation of dense solid-liquid slurry in the presence of polymer flocculants. The synthesis of amphiphilic polymer flocculants. The flocculation of oil sands tailings by two stage polymer treatment followed by vacuum or pressure filtration, while the polymers were selected from groups of different molecular weights and ionic characters. The depositional behavior of the polymer-flocculated tailings, and an investigation of the polymer-mineral interaction mechanisms studied by sum frequency generation vibrational spectroscopy.

## 5. Challenges encountered

The dewatering of the oil sands tailings is a unique problem unlike the typical mine tailings. Although the mature fine tailings in the oil sands tailings ponds are known to contain 30-40 wt% fine solids with particle sizes below 44 µm, the fine particle size is in fact not the only reason for the challenge in dewatering. We had tested a kaolinite slurry at 37 wt% solids where the kaolinite particles had a mean size of 0.6 µm, an order of magnitude smaller than the particles in oil sands mature fine tailings. Yet a filter press filtration of the kaolinite slurry, without the use of any polymer flocculant, easily produced filter cakes reaching 67 wt% solids. The challenge of the oil sands tailings dewatering is the presence of the residual bitumen and organic matter.

Being the first multi-facet research effort spanning across four geological locations, involving four research institutions and eight principal investigators, we ran into significant challenges in coordinating the research effort. The major bottleneck was getting the research agreement in place to start the project. Some phases of the project had a one-year delay for the three-year project.

## 6. Conclusions (non-confidential)

Amendment of the tailings slurry by polymer flocculants (chemical means) followed by mechanical solid-liquid separation methods (physical means) is the only potential way to remediate the oil sands tailings problem. In this project, we have built a simulation model (a “numeric rheometer”) to directly simulate the mixing and aggregation of fine particles in dense slurry in the presence of polymer flocculants. We synthesized and tested amphiphilic co-polymers, tested commercially available polymers with different molecular weights and ionic characters, in two stage sequential treatment of the tailings. We investigated the filtration and depositional behaviors of the polymer amended oil sands tailings. This holistic approach yielded large amount of useful information and laid the foundation to further R&D work.

The key results showed that amphiphilic polymers with both hydrophilic and hydrophobic components had better dewatering performance than the usually only hydrophilic polymer flocculants. Two-stage sequential addition of the polymers demonstrated much better dewatering then either polymer was used alone. Filter press pressure filtration of mature fine tailings treated by the two-stage polymers could generate filter cakes with high solid contents.

## 7. Benefits and outcomes

This project was the first attempt of relating several aspects of polymer amendment of oil sands tailings, from simulating the mixing and aggregation behavior of the tailings in the presence of the polymer, to flocculation treatment followed by filtration or deposition, to synthesize new polymer flocculants and fundamental studies to understand the polymer adsorption mechanisms on the fine solids surfaces. Through the project, thirty graduate students, undergraduate students and postdoctoral researchers were trained, and the results led us a step closer to achieve the ultimate goal rapid dewatering to 75+ wt% solids in the treated oil sands tailings.

## 8. Next steps for R&D in this area

Further R&D should focus on identifying the detrimental roles of residual bitumen and organic matter in the oil sands tailings on dewatering, and identifying the remediation measures to overcome these detrimental roles. Afterwards, the two-stage polymer amendment procedure developed in this project can be used (using different polymers), followed by the conventional mechanical dewatering operations (such as filtration) to reach the 75+ wt% solids target.