Canada's Oil Sands Innovation Alliance (COSIA), and

Institute for Oil Sands Innovation (IOSI) at the University of Alberta

Call for Full Proposals

Deadline: February 15, 2022, 23:59 MST

on the following topics:

- Fines-dominated tailings dewatering
- Understanding flow characteristics of FFT during harvesting activities at different elevations of tailings ponds
- Generation of reduced sulfur compounds in tailings
- Methods for controlling mixing in a deposit formed through co-deposition
- Methane oxidation in tailings ponds and impact on fugitive greenhouse gas (GHG) emissions.

Please refer to pages 3-16 for the detailed Requests for Full Proposals. The earliest start date of the projects is January 1, 2023.

Application Process:

- Familiarize yourself with the conditions for participation in the IOSI/COSIA projects (page 2). If you require more details, contact the IOSI director Natalia Semagina at semagina@ualberta.ca. The terms are non-negotiable. Before the proposal development, please ensure that you and your organization will be able to enter into the research agreement.
- The full proposal template is attached below (page 17). The proposal Word and budget Excel templates are available at https://iosi-alberta.ca/forms/.
- There are no restrictions on the number of proposals per applicant.
- Please email the proposal with the required embedded forms as one pdf file to iosi@ualberta.ca by February 15, 2022, 23:59 MST.

Selected Terms and Conditions for Researcher Participation in IOSI/COSIA Projects

The terms and conditions are provided through the Foundation Agreement between the University of Alberta (UofA) and Imperial Oil Limited, as well as through the Prime Agreement with Alberta Innovates and Agreement with Canada's Oil Sands Innovation Alliance (COSIA). Agreement to these terms will be required if the proposal is accepted for funding. If you have questions before the proposal submission, please contact IOSI Director at semagina@ualberta.ca.

IOSI/COSIA will work with researchers to establish and monitor the progress of research projects, and to ensure that procedures for publication, disclosure of intellectual property, and maintaining confidentiality are followed. Recipients of IOSI/COSIA funding (the organization of the principal investigator will be named as a Research Provider) must agree to the following conditions:

1) **Intellectual property (IP)** – The new IP shall be owned by the Research Provider. Certain rights to use the new IP will be granted to the UofA, Imperial Oil Limited and COSIA. Certain rights to use and publish the produced reports will be granted to Alberta Innovates.

2) **Confidentiality** – All researchers shall use all reasonable efforts to prevent disclosure to third parties of any confidential information provided by the UofA, Imperial Oil Limited, or COSIA. This obligation does not apply if the information is already known to the researcher, or is revealed by third parties who have no duty to maintain such confidentiality, or after 10 years of receipt of the information.

3) **Publication rights** – IOSI and COSIA must be provided with copies of all theses, abstracts, presentations, and manuscripts prior to the submission for publication to permit review for confidential or business-sensitive information.

4) **Project reviews** – The projects shall be subject to a staged review process to ensure progress and relevance.

5) **Salary** – IOSI emphasizes on training of highly qualified personnel. Therefore, IOSI funds are not to be used to cover the honorarium or salary/benefits of the principal investigators.

6) **Termination** – Either party may terminate the Project Agreement within not less than 30 or 90 days, depending on the cause.

Updated: November 23, 2021

Fines-Dominated Tailings Dewatering

Background

Fine dominated tailings, defined as over 50 wt% of <44 μm size fraction in tailings, are challenging to manage. Fine tailings usually contain significant amount of clays, which make them difficult to dewater and consolidate due to low permeability. Over four decades, chemical aids (e.g. flocculants/coagulants) have been used to improve fine tailings dewatering with or without mechanical (e.g. centrifuge, etc.) enhancement [1]. Many technologies have been tried without much success in commercial operations due to techno-economic feasibility issues. For example, some operations manage to produce a centrifuge cake with 55 wt% solids from the flocculated mature fine tailings, but it is still not ready for reclamation.

Extensive research has been conducted to understand the fundamentals of fines tailings dewatering and consolidations, including the following topics:

- Characterization of fluid fine tailings and their interaction with bitumen/organics ([1],[2]);
- Evaluation of the effects of different flocculants, coagulants, modifiers of surface hydrophobicity/ rheological properties on settling and centrifugation and filtration in laboratory, pilot testing and commercial operations [3];
- Impact of bitumen in tailings settling and consolidation [4];
- Effect of mixing and shearing on fluid fine tailings flocculation and transportation [5]; and
- Chemical assisted mechanical dewatering using centrifuge or filter press [6].

These studies have improved our understanding of both fundamental mechanism and operation performance. No breakthrough has yet been made that achieves dewatered the fines tailings with over 60 wt% solids economically.

Statement of Research Opportunity

The new solution is expected to treat the fluid fine tailings produced from the conventional minable bitumen extraction process to obtain fines tailings with >60 wt% (+/-5 wt%) solids consistently through a microbiological, chemical, or mechanical process, or their combination.

Desired Results

Better understanding of surface modification mechanisms of fines tailings particles must ultimately result in practical ways of dewatering fine dominated tailings to reach over 60 wt% solids. This should allow the fine tailings to be disposed along with coarse tailings to a dedicated deposition area economically and would reduce or eliminate the needs for fine tailings impoundments.

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Understanding flow characteristics of FFT during harvesting activities at different elevations of tailings ponds

Background

Management of fluid fine tailings (FFT) in oil sands operations requires harvesting it from tailings ponds and its subsequent pumping followed by chemical/mechanical treatment. One of the challenges during harvesting of FFT is cone formation between the clear water and tailings, which adversely affects the density of FFT and its consistent delivery to the tailings processing facilities. Oil sands industry is interested to understand the role of FFT characteristics (rheology, thixotropy, density and sand to fines ratio) on cone formation and potential mitigation methods.

This phenomenon has been studied in the mining industry [1] and one of the suggested mitigation measures has been use of caissons [2].

Statement of Research Opportunity

Improvement in harvesting a consistent flow of FFT by mitigating the effect of cone formation (using different methods, including caissons).

Desired Results

The proposed method should include modelling and potentially experimental study of cone formation in presence of a caisson, to address the following aspects:

- Fundamental understanding of the role of non-Newtonian behavior and thixotropy of FFT on cone formation in presence of a caisson;
- Methods to assess the extent of coning in presence of a caisson (e.g. computational fluid dynamics modelling; experimental laboratory study); and
- Other potential strategies that mitigate/reduce the effect of cone formation and allow consistent flow of FFT.

Works Cited

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[2] Svorcan, R. 2015. Recovering mature fine tailings from oil sands tailings ponds. Technika Engineering Ltd. (U.S Patent: 9,127,427).

Generation of Reduced Sulfur Compounds in Tailings

Background

Biodegradation of residual hydrocarbons in oil sands tailings leads to generation of greenhouse gases (GHG) such as methane (CH_4) and carbon dioxide (CO_2) as well as a range of reduced sulfur compounds [1]. While all types of tailings support such microbial activities to some extent, froth treatment tailings (FTT) that include bioavailable naphthenic or paraffinic solvents are known to be the major source of such emissions. The n-alkanes and BTEX compounds found in naphtha, for example, stimulate the biological production of GHGs as reported extensively in the literature ([2], [3]). Different microbial communities are present in the tailing ponds including but not limited to methanogens, iron reducing bacteria (IRB), and sulfate reducing bacteria (SRB) each producing a specific product with a certain kinetics. SRBs, for example, consume sulfate and produce HS^- that could escape as H_2S [4]. In some tailings treatment options, sulfate is added either as gypsum or a coagulant (Alum or Ferric sulfate) leading to an increase of sulfate concentration in tailings. Presence of sulfate and hydrocarbons in tailings provides the SRBs with the substrates needed for H_2S production. The kinetics of CH_4, CO_2, and H_2S generation in tailings at presence of different electron acceptors have been studied extensively in the past as summarized in [5] and references therein. One aspect that is not yet studied in detail in tailings is the generation of reduced sulphur compounds (RSCs). RSCs are a group of compounds generated from natural and anthropogenic sources with sulfur atoms in their lowest oxidation state. The most common RSCs in the environment include H_2S, carbonyl sulphide (COS), methane thiol, dimethyl sulphide, carbon disulphide, and dimethyl disulphide [6]. Some past studies have shown that RSCs could be originated from the light hydrocarbons in tailings [7], although the results are not conclusive. As such, the origin of RSCs and the variables that would impact their generation and kinetics require additional investigation.

Statement of Research Opportunity

Funding opportunities are available for fundamental research focused on understanding the RSCs generation in tailings and FTT affected tailings. The impact of various treatments on the generation and kinetics of the RSCs and particularly carbonyl sulfides is of interest.

Desired Results

The research project should provide an understanding of the origins and kinetics of RSCs generation in tailings. Particularly, understanding if light hydrocarbons (naphtha or paraffinic solvents), HPAM polymers used for flocculation, sulphate concentration, and presence of nutrients could have an impact on the generation of RSCs.

Works Cited

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Methods for Controlling Mixing in a Deposit Formed through Co-deposition

Background

Oil sands mining typically produces multiple and characteristically different tailings streams. This may include "whole tailings" and froth treatment tailings but depending on the specific details and history of the extraction process and tailings management strategy, may also include other streams containing specific fractions of the whole tailings stream and chemical additives (flocculants and coagulants). These streams are then often strategically deposited back into tailings storage facilities to meet various objectives. Coarser untreated streams may form components of the containing structure, while the treated higher fines streams are typically deposited in specific and isolated areas to support various reclamation objectives. Depending on the pour strategy, some streams may be deposited close to each other without explicit isolation using constructed dykes. Mixing of these streams can occur and form a composite material that behaves differently from the original tailings streams. Reclamation objectives may require minimizing the formation of any mixed materials to ensure that reclamation strategies predetermined for the two original tailings streams are not undermined. Conversely, other deposition strategies may rely on this mixing to meet specific reclamation objectives for a deposit.

Some existing tailings strategies include the technique of forming an intermediate fines deposit that relies on this mixing behaviour. Froth treatment tailings, thickened tailings (TT) resulting from thickening the hydrocyclone overflow in a conventional thickener with a polymeric flocculant, and coarse sand tailings (CST) resulting from the hydrocyclone underflow can be deposited next to each other on a beach. The resultant composite material has shown an elevated sand to fines ratio (SFR) averaging around 2.5 while still achieving the target solids contents averaging above 70 wt.% [1]. Other mixing strategies, including centrifuge product and CST (e.g., Canadian Natural's Albian), can consistently achieve SFRs as low as 2 and average solids contents above 75 wt.%.

Beach below water deposits can be relatively well mixed resulting in a desirable homogeneous material bearing a composition that is not similar to either component stream. However, they can also be poorly mixed, resulting in undesirable heterogeneous interbedded layers whose composition indicates that one or the other component stream was the primary contributor at the time of deposition. For both scenarios, a better understanding of the potential methods for controlling the extent of mixing and homogeneity of the resulting mixture can contribute to more effective deposition planning and reduced risk profiles for the resultant deposits.

Statement of Research Opportunity

Some practical considerations can influence the degree of mixing between multiple streams. Previous work conducted across the industry and specifically on a mixed deposit at Muskeg River mine [2], proposes that the fines capture (driven, in this case, by mixing between the higher fines streams and CST) can be influenced by practical modifications to the deposition strategy. This list includes, but is not limited to:

- Modifying the deposition location (the flow state that each stream is in at the point that they are merged);
- Modifying the deposition velocity (via diffusers or nozzle) or deposition energy (spoons/spigots);
- Earthworks to modify the overland flow paths (e.g., jetties perpendicular the beach, controlled beaching/polders);
- Controlling the pond elevation/beach length to influence the potential distance over which mixing can occur, as well as the proportion of "beach-above-water" and "beach-below-water" deposit being formed; and
- Modifying the solids content of the streams.

An assessment of some of these factors and their predicted impact on the area and homogeneity of the resultant mixed deposits can help inform and optimize deposition strategies in the future. Both computer modelling ([3], [4]) and larger scale laboratory studies have been informative in understanding the drivers and processes that influence mixing. Extensions of this work may provide practical guidance that can be implemented at a field level for further validation.

The various streams potentially subject to mixing possess varying compositions and rheological properties. A project assessing the mixing potential of a low SFR (<0.5) stream and a high SFR (>4.0) stream, as well as a low bitumen (<3 wt.%) and high bitumen (>9 wt.%) content may provide insight that can be readily applied to many of the mixing scenarios relevant in the industry. Variability in mixing behaviour has also been observed between centrifuged fluid fine tailings (CFFT) and polymer-amended FFT at similar solids contents (45-50 wt. % and SFR >0.2); so assessing the influence of the modified rheological properties imposed by centrifugation may also provide valuable insight.

Desired Results

The desired outcome of this research will be a set of recommendations that presents the best pour strategies to drive mixing over a large or small footprint, and how to best encourage homogenous or heterogeneous interbedded deposits so these strategies can be implemented as required, depending on the specific deposition objectives. It is however acknowledged that the desired broad practical recommendations may be unrealistic, and that more focused recommendations evaluating the impact of one or two critical variables on "mixing potential" may be more appropriate.

Though qualitative recommendations are the expectation, recommended deposition strategies with critical measurements, such as spigot spacing or critical flow rates, would ideally be presented with quantitative outputs for future validation.

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Methane Oxidation in Tailings Ponds and Impact on Fugitive Greenhouse Gas (GHG) Emissions

Background

Compared to the majority of tailings generated during hot water extraction of bitumen from mined oil sands, froth treatment tailings (FTT) are a relatively small waste stream that contain several components that can lead to specific biogeochemical concerns that may affect the operations, tailings management, and final closure and reclamation of the oil sands site. These include elevated levels of sulfide minerals that under some circumstances may lead to acid rock drainage (ARD), naturally occurring radioactive materials (NORMs) [1], and hydrocarbons that can result in gas generation due to biological activity ([2], [3], [4], [5]). These materials must be managed appropriately throughout the life of the mine to ensure closure objectives for the site are met.

Froth treatment tailings are similar to other tailings slurries in that they contain various mineral solids and small amounts of unrecovered bitumen. However, they also contain residual quantities of light hydrocarbons such as naphtha or paraffinic diluents that are used in froth treatment. After deposition of FTT in a tailings pond, the residual hydrocarbons can be degraded through many complex biological processes including aerobic, iron reducing, and sulphate reducing processes, as well as through methanogenesis ([3], [4], [6], [7], [8]). These processes can result in the generation of gases such as carbon dioxide, hydrogen sulphide and methane ([2], [8], [9]) which may be present in dissolved or ex-solved form. Transport of gases may affect tailings dewatering and consolidation. Ebullition of gas bubbles to the surfaces of deposits contributes to the GHG emissions of an oil sands site.

Microbial degradation of light hydrocarbons in FTT-affected tailings has been investigated in several laboratory studies using both model and field samples ([7], [10], [11], [12], [13], [14]). Work completed by COSIA [15] established a regional picture of some pertinent degradation pathways and the involved microbial communities. Other work addressed the circumstances that result in gas bubble evolution and release ([2], [3], [15], [16], [17]). The sources of GHGs, reduced sulphur compounds (RSCs) and volatile organic compounds (VOCs) were related to the chemistry of FTT and the various microbial processes involved in the degradation of light hydrocarbons in a recent review by Van Dongen et. al. [5].

Predicting gas generation from FTT-affected deposits has received more attention in the last few years as gases produced from biological activity may result in surface emissions of GHGs, which have been reported in several studies ([2], [6], [18], [19], [20]). Modelling and predicting GHG emissions from tailings ponds is challenging for numerous reasons; including the fact that tailings are heterogeneous and may occur as mixed deposits of FTT and other extraction tailings ([5], [21]). The biological processes involved are complex and may occur concurrently. A significant lag can also exist between the establishment of relevant microbial communities and observed gas generation [3]. Phenomena related to the transport and release of gas at surface must be understood in addition to gas generation mechanisms.

Models depicting gas generation from tailings have been developed in recent years; notably, a kinetic model was established by Siddique [12], with improvements proposed a decade later [21], while an equilibrium model relating emission intensity to diluent loss and the properties of diluent was proposed by Burkes [4]. In the latter, methane and carbon dioxide emissions were estimated based on the properties and amount of fermentable substrate originating from residual diluent, as well as assumptions about losses to VOC, consumption of carbon during aerobic degradation, sulphate reduction, and methanogenesis. The fugitive GHG intensity from FTT-affected tailings ponds was estimated to be less than 1 g CO_2eq/MJ bitumen produced for a typical oil sands operation.

Much study has been devoted to understanding methane generation in tailings ponds and potential future emissions profiles. It is important to note that interception and conversion of methane, produced during anaerobic degradation, to carbon dioxide in oxic, shallower environments prior to efflux may result in a reduction in GHG emission intensity due to the lower global warming potential of carbon dioxide compared to methane ([22], [23]). Methane oxidation has been observed in many natural sites such as lakes, ponds and swamps ([24], [25], [26]); see also other references within Le Mer and Roger [27]. This phenomenon has also been noted at agricultural sites such as rice fields [28]; see other references within Le Mer and Roger [27] and industrial sites with oil-impacted soils ([29], [30]) and those references within. In the oil sands context, methane oxidation in diluent degradation phenomena has been noted [6], specifically Saidi-Mehrabad et al. investigated methanotrophic communities that were detected in surface waters of a tailings pond [31]. They measured methanotrophic potential of surface waters and identified several environmental factors influencing the presence of methanotrophic species, such as alkalinity, salinity, ammonia and oxygen content, and temperature.

Statement of Research Opportunity

While methane oxidation has been researched in other contexts and to some degree in the oil sands application, the relative importance of methane oxidation as a mechanism that may influence GHG emissions from a tailings pond is not well understood. It is of interest to comprehend the significance of methane oxidation on the GHG emission profile of a tailings pond, by better understanding the biogeochemical conditions that lead to methane oxidation and the potential impact of concurrent biological processes occurring in anoxic and oxic zones of tailings deposits.

Desired Results

An understanding of the relationship between methane oxidation and other gas generating phenomena that occur in deep and shallower zones of tailings ponds is sought, including ideally a quantitative assessment as to the proportion of anaerobically generated methane that may be intercepted and oxidized before it reaches the surface as a GHG emission.

A better understanding of the circumstances favoring methane oxidation, relative to other metabolic pathways, is also sought, including knowledge of the conditions within a tailings pond that lead to methane interception and subsequent oxidation. For example, understanding how temperature, geochemistry, presence of certain biological communities, relative thickness and/or location of FTT affected tailings within a pond, as well as properties of overlying surface waters, affect the likelihood that anaerobically generated methane will be oxidized before being emitted as a surface GHG may be relevant.

Another goal could be to understand the relative importance of methane oxidation in FTT-affected fluid fine tailings deposits, typically overlaid by surface water, when compared to FTT-affected beach above water deposits that may be only partially saturated.

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The word file template with embedded links is available at the IOSI website under "Forms" https://iosi-alberta.ca/forms

Full Project Proposal
submitted to the Institute for Oil Sands Innovation (IOSI) and
Canada's Oil Sands Innovation Alliance (COSIA)

Theme:

Commented [NS1]: Please specify one of the following themes: Fines-dominated tailings dewatering; Understanding flow characteristics of FFT during harvesting activities at different elevations of tailings ponds; Generation of reduced sulfur compounds in tailings; Methods for controlling mixing in a deposit formed through co-deposition; or Methane oxidation in tailings ponds and impact on fugitive greenhouse gas (GHG) emissions.

PROJECT TITLE

Principal investigator: (name, affiliation, full address, phone number and email)

Co-investigators: (name, affiliation, and email for each co-investigator; do not include trainees or other research/technical personnel)

Funding requested each project year and total (including overhead)**:**

I, principal investigator, acknowledge, that co-investigators and I reviewed terms and conditions of researcher participation in IOSI/COSIA projects. We understand that we will be required to agree to those terms and conditions, if the project is approved for funding: *select* YES/NO

Commented [NS2]: The Selected Terms can be found at the IOSI website https://iosi-alberta.ca/forms/ The terms are non-negotiable. If you require more details or have questions, please contact IOSI Director Natalia Semagina at semagina@ualberta.ca for the full list of conditions prior to the proposal preparation/submission.

Submission date: xx, month, 20xx

1. **Research proposal** *(maximum 4 single-spaced pages)*

Shortly describe the background (the proposals will be evaluated by technical experts in the field, so please avoid general background and address only the specific questions from the Requests for Proposals). Describe the research objectives. Address the novelty of the proposed research and expected outcomes. Include detailed methodology. Provide activity schedule. Identify the indicators for monitoring progress during the project and for assessing the outcomes.

2. **Available and requested infrastructure and consumables** *(maximum 1 single-spaced page)*

Provide details if the infrastructure (equipment, space, etc.) is in place (PI or co-PI's laboratories or if you have access to the required equipment for user's fees). Please review the equipment available at the IOSI Laboratory (https://iosi-alberta.ca/lab/). The laboratory services and training are free to IOSI researchers, subject to selected consumables and materials. Explain in detail in your proposal if you plan to use some IOSI laboratory services or equipment, approximately at what frequency and for how many samples or hours. If new equipment is absolutely needed for the project, provide justification.
Describe if your research requires tailings samples and how much. One can purchase mature fluid tailings (MFT) samples from the Sample Bank at Innotech Alberta https://innotechalberta.ca/services/reservoir-geosciences/ore-and-mft-sample-banks/. Explain if larger quantities or other samples are need.

3. **Team** *(maximum 1 single-spaced page)*

Explain how the knowledge, experience and achievements of principal investigator, co-investigators and other key staff will provide the expertise needed to accomplish the project objectives.

4. **Training plan** *(maximum 1 single-spaced page)*

Include categories of the trainees (PhD student, etc.), their number, their roles in the project. Describe what technical and other skills they will acquire during the project.

5. **References** *(maximum 2 single-spaced pages)*

Citations should include all authors, full titles of the cited articles (patents, book chapters), journal title, volume, year and pages in any format.

6. **Budget**

Fill out the Excel Budget template from the IOSI website https://iosi-alberta.ca/forms/, copy-paste the table here. Provide a brief justification for the expenditures.

Address the following mandatory questions:

1) *requested overhead rate (for projects external to the UofA) based on the organization's policy but up to a maximum of 25% as per IOSI regulations.*
2) *is the PI eligible to apply for NSERC matching via Alliance grant program?*
3) *if the answer is "yes" in question 2, explain your organization policy on the indirect cost of research if the project is co-funded by NSERC: is the overhead charged to the partner organization and at what rate?*

7. Relationship to other research support

Include only those projects which have overlap with the proposed project (for all involved investigators).

8. Personal data form

Only for the principal investigator and co-investigators, do not include trainees. The form can be in any format (CCV, CV, resume with included publications, etc.) but it must demonstrate the investigator's expertise to undertake the proposed research.

Please submit the proposal and CV attachment(s) as one pdf file,
by February 15 (Tuesday), 23:59 MST, to iosi@ualberta.ca