OIL SANDS TECHNOLOGY TO MEET THE CHALLENGES OF NEW WORLD SUSTAINABLE TAILINGS MANAGEMENT

International Oil Sands Tailings Conference
December 4-7, 2016
Integrated approach towards sustainable remediation of OS tailings

2015
Alberta Climate Change Leadership Plan
- Reduce methane emissions by 45%
- 100 megatonne cap on industry emissions

2015
Canadian Council of Academies
- Keep FT tailings out of ponds
- Treat FT tailings separately
- Recover bitumen and minerals

2016
Alberta Energy Regulator Directive 85
- Requires “Ready to Reclaim” tailings deposition
- Secondary objective to address froth treatment tailings, gas emissions, acidification
- Minimize environmental effects of deposition

2012
COSIA Oil Sands Tailings Technology Deployment Roadmap
- address lost solvent, pyrite, NORMs
Froth treatment tailings are environmentally and economically significant (although volumes are much smaller than extraction tailings)

- FTT are a mixture of water, sand, fine clays, hydrocarbons, representing 6-10% of total tailings volumes
- FTT tailings also contain the most environmentally damaging elements
  - 100% of methane producing solvents, VOC and SOA source
  - 95% of radioactives
- FTT contain most recoverable economic value
  - 100% of solvent losses
  - 95% of heavy minerals
  - 25% of bitumen losses

![FTT Share of Total Tailings](image)
Titanium’s CVW™ technology is designed to intercept FTT before discharge to ponds and recover valuable minerals, lost bitumen, solvents and water.

- 2010-2013 integrated demo
- Industry-standard scale
- Validated by stakeholders
- 13 patents in IP portfolio

Titanium’s CVW™ is a SDTC portfolio technology, demonstrated at Natural Resources Canada’s CanmetENERGY oil sands commercial pilot facilities in Devon, Alberta with the support of government and a consortium of oil sands firms.
Titanium’s innovation - efficient sequential hydrocarbons removal

Unlocks additional potential for enhancing tailings management
Froth Treatment Tailings Management

- Froth treatment tailings have a relatively high amount of fines material
- Further complicated by relatively high amounts of bitumen and solvent
- Titanium processing classifies solids into a fines-enriched tailings; coarse stream to HM process
- CVW efficiently recovers hydrocarbons; tailings dewatering with high fines capture
Tailings Management
Tailings consolidation, water and heat recovery

Tailings and Water Quality Specs

<table>
<thead>
<tr>
<th>Species (mg/L), Property</th>
<th>FT Tailings</th>
<th>Produced water</th>
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<tbody>
<tr>
<td>Cl</td>
<td>384-525</td>
<td>384-508</td>
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<tr>
<td>SO₄</td>
<td>223-503</td>
<td>215-461</td>
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<tr>
<td>NO₂</td>
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<td>8.2-12.9</td>
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<tr>
<td>NO₃</td>
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<td>0</td>
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<td>Ca</td>
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<tr>
<td>Na</td>
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<tr>
<td>K</td>
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<td>S</td>
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<td>CO₃</td>
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<td>pH</td>
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<td>Conductance (mS/cm)</td>
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<td>TSS</td>
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<tr>
<td>O&amp;G</td>
<td>316</td>
<td>0.92</td>
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<tr>
<td>Surface tension (mN/m)</td>
<td>61.5</td>
<td>61.5</td>
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</tbody>
</table>

- TM feed from hydrocarbon removal tailings
- Thickened underflow, C-cake at to 50-60% solids
- Flocculent (200-400 ppm SNF 3338)
- Enhanced performance due to low hydrocarbons
- 80% water recovery at 70°C (~0.1 Mt/a GHG offset)
- Water suitable for recycle or low grade utilities
- Potential to reduce fresh water usage by over 10%
- Thickened tailings suitable for enhanced tailings management processing/thin lift
Enhanced Tailings Management

• Consolidation of contained fine solids enhanced due to low concentrations of bitumen

Achieve solids concentrations of 75% within one year, exceeding mandated depositional strength

In part, early stage consolidation enhanced by reduced bulk or steric interference

Consolidation at low flocculant dosage

1100 ppmw

- Excellent consolidation behaviour at polymer dosing of less than 400 ppmw (vs industry avg ~1000 ppmw)


Enhanced Tailings Management

Enhanced Tailings Management

- Fine solids consolidation enhanced at high solids densities due to low bitumen concentrations
- In part, consolidation is improved by reduced colloidal pressure between fines particles


Fugitive GHG/methane/VOC emissions and other challenges from Oil Sands Tailings and Ponds


Air Emissions
A = Rapid volatization of VOCs as hot tailings solvents are discharged into the atmosphere
B = VOCs volatized from oily films at pond surface (slicks), SOA precursors
C = Anaerobic fermentation of solvents into methane (methanogenesis)
D = Compound cycling results in fixed carbon (bitumen/solvent) trapped in tailings

Water Quality
Dispersed fine particles and residual hydrocarbons limit reuse applications

Tailings Management
Mature Fine Tailings (MFT) – non-segregating dispersion of fines and clays; trapped bitumen further impedes reclamation efforts (centrifugation, thin lift deposition)

Emerging Issues
Concentration and deposition of radioactive solids (Canadian NORM management) and pyrite (acid rock drainage)
Fugitive GHG Emissions Abatement

- Froth treatment tailings are the largest source of fugitive GHG emissions at oil sands site
- Tailings pond GHG emissions can represent up to 90% of fugitive losses; 10% site-wide emissions
- Tailings pond methane emissions result from microbial fermentation of FTT naphtha
- Titanium’s CVW™ removes 80% of tailings pond methane emissions; 50-70% of total fugitives
VOC and SOA abatement

- Froth treatment tailings are the largest source of fugitive VOC emissions at oil sands site
- Titanium’s tailings solvent recovery technology reduces pond deposition of hot naphtha from FTT
- CVW$^\text{TM}$ reduces oil sands VOC emissions by over 70% site-wide
- Recovery of semi- and intermediate volatility hydrocarbons from FTT contributes to SOA abatement


Based on mining production reported by “Crude Oil: Forecast, markets and Transportation”, Canadian Association of Petroleum Producers, June 2016.
Pyrite and NORM management

- Up to 80% radioactivity and 70% pyrite removed from bulk fluid tailings
- Radioactivity can be concentrated into small tonnage MSP tailings and HM products
- Pyrite concentrated into a smaller tonnage MSP tailings stream (2% of FTT volume)
- Potential for clean dry landscape reclamation with efficient management of challenging minerals
Titanium’s CVW™ end-to-end tailings solution for froth treatment tailings offers potential to avoid tailings ponds completely, improving tailings management and reducing costs.

Tailings bitumen and solvent recovered using Titanium’s patented CVW™ technologies, deliver GHGe methane reductions (up to 1 Mt/yr/site) & VOC emissions reductions (10kt/yr/site).

Minerals exhibiting radioactivity are segregated into minerals concentrates and transported off-site, leading to 80% reduction in radioactivity in beached sands.

Thickener operates at reduced polymer dosages (by up to 67%) and enhanced performance allows for heat recovery and integration, further offsetting GHG emissions (~0.1 Mt/yr/site). Fit-for-reuse water recycled to process applications and/or low grade utility purposes to offset fresh water intake from Athabasca River.

Tailings dewater efficiently to exceed 5 kPa strength in less than 1 year; accelerate trafficability and reduce fines loading to tailings pond.

Fit-for-reuse water recycled to extraction process.

Summary

• Emerging sustainable landscape for oil sands mining – Directive 85 calls for a holistic approach to reclamation that addresses environmental performance on a number of dimensions and identifies froth treatment tailings as higher risk

• Froth treatment tailings are a significant source of environmental challenges including fugitive methane emissions, VOC and SOA emissions...

• Titanium’s integrated CVW™ process offers an end-to-end tailings management solution that can avoid pond deposition, abates air emissions issues and improves water usage efficiency

• CVW™ has positive economics: Recovered bitumen and solvent of sufficient quality for SCO feedstock; valuable heavy minerals suitable for global markets