Organic Residuals for Mine Reclamation: an Overview of Progress in Ontario

Bryan Tisch

Compost Council of Canada, Webinar
November 5, 2014
Outline

- Overview of mining issues (Mining 101)
- Success with papermill biosolids
- Green Mines Green Energy Initiative
- Moving forward – biochar/carbon in tailings
What are Tailings?

- Material rejected from a mill after most of the recoverable valuable minerals have been extracted.
Sulphide Oxidation

- Acid generating process:

\[ 2\text{MS} + 3\text{O}_2 + 2\text{H}_2\text{O} \leftrightarrow 2\text{H}_2\text{SO}_4 + 2\text{M}_{(aq)} \]
Offsite Effects - Dust and Drainage
Growth Constraints in Mine Waste

- Particle size and structure
- Compaction
- Lack of organic matter
- Lack of nutrients
- Lack of soil microbes
- pH
- Metals
Background

- Work with papermill biosolids initiated at several sites in Ontario (Rio Algom, Vale, Goldcorp)
- Vale (formerly INCO), Glencore (formerly Falconbridge) and city of Toronto - possibility of using composted garbage as a reclamation material for mines.
- Proposed biodiesel plant in Sudbury
Pronto Mine – Elliot Lake

• First tailings reclamation in Ontario with papermill biosolids.
• Excellent vegetation establishment.
• Mining company estimated savings of $2 million
• Paper company biosolids disposal cost halved.
Vale – Copper Cliff

1999

2008
Vale – Copper Cliff

2004 Assessment

No negative effects from biosolids cover after ~ 5 years.
Goldcorp – Coniaurum Mine
Policy Linkages

**NRCan**

**Organic waste suppliers** – no commitment until mines agree to take material

**Mines** - no commitment until regulators willing to approve

**Regulators** – no approval until impacts investigated
Green Mines Green Energy (GMGE)

- 3-year field demonstration study led by NRCan to examine technical feasibility of using residuals

- **Goal** - To advance mine reclamation through the beneficial use of organic residuals for the sustainable establishment of bioenergy crops

- Potential to contribute feedstock for a planned 20 million litre/year biodiesel plant in Sudbury
Scope of the Initiative

Four main target areas proposed:

- Impact of Organic Residuals on Tailings
- Quantity and Quality of Biomass
- Economic Feasibility
- Communication, Public Education and Technology Transfer
Primary Participants

**Mining**: Glencore, Vale, Goldcorp, Barrick Gold, Highland Valley Copper, Enterprise Cape Breton

**Forestry**: Domtar, St. Marys Paper, Abitibi Consolidated

**Government**: Natural Resources Canada, Agriculture Canada, Ont. Ministry of Food & Rural Affairs, Ont. Ministry of Environment

**Academia/Other**: Laurentian University/MIRARCO, GroBark, City of Greater Sudbury, Metro Vancouver, Green Municipal Fund, NSERC, ORF
Demonstration Locations

- Vale (Copper Cliff) – acidic Cu/Ni tailings
- Glencore (Onaping) – desulphurized slimes layer overlying acidic Cu/Ni tailings
- Goldcorp (Timmins) – alkaline gold tailings (As bearing)
- Cape Breton (ECBC)
- British Columbia (Highand Valley Copper)
Potential Benefits of Residuals

- Tailings dust suppression
- Growth substrate
- Decreased metal mobility
- Progressive reclamation
- Reduced liability for mine waste
- One waste to reclaim another
- Carbon credits
- Biodiversity
- Alternative land use (long term)
- Diversion of organics from landfill
Vale Biosolids Delivery
(Winter 2008)
Vale – St. Marys Tilling (May 2008)
Vale - St. Marys (May 2008)

~3,500 m³ delivered and spread (0.5 ha)
Glencore (June 2009)
Vale
Corn/Canola
Biomass – corn/canola

*Seed Yield Ontario Agr. Avg. (2009) was 2.2 T/ha
Switchgrass

![Switchgrass field](image)

**Biomass (T/ha DW)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Cave-In-Rock</th>
<th>Sunburst</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>2010</td>
<td>0.3</td>
<td>0.9</td>
</tr>
<tr>
<td>2011</td>
<td>1.2</td>
<td>1.6</td>
</tr>
</tbody>
</table>

**Legend:**
- Cave-In-Rock
- Sunburst

**Note:**
- Data represents biomass of Switchgrass in terms of dry weight (T/ha DW) for the years 2009, 2010, and 2011.
Sunflower (2011)

Biomass (2011)
Vale = 7.8 +/- 1.7 T/ha (DW)
Xstrata = 7.2 +/- 1.7 T/ha (DW)
Willows
Willows
Rough Economics/Energy

- Based on GMGE field results….
- Sale of biomass also feasible (consideration for companies not interested in actually producing biofuel)
- Potential profit of $905/ha/yr for canola at Vale. If applied to 60% of their tailings (1,300 ha)...approx. $1.2 million/yr....just on sale of feedstock. Could generate up to $4.7 million litres/yr of biodiesel.

<table>
<thead>
<tr>
<th>Site</th>
<th>Crop</th>
<th>Yield (kg ha⁻¹)</th>
<th>Profit ($ ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vale St. Marys</td>
<td>Canola</td>
<td>3,273 (seed)</td>
<td>905</td>
</tr>
<tr>
<td></td>
<td>Corn</td>
<td>3,378 (seed)</td>
<td>-350</td>
</tr>
<tr>
<td>Goldcorp</td>
<td>Canola</td>
<td>2,748 (seed)</td>
<td>612</td>
</tr>
<tr>
<td>Glencore</td>
<td>Canola</td>
<td>706 (seed)</td>
<td>-363</td>
</tr>
<tr>
<td></td>
<td>Corn</td>
<td>2,469 (seed)</td>
<td>-515</td>
</tr>
</tbody>
</table>
Groundwater Nickel (Vale)
Column Study – 5 year duration
Goldcorp (Delnite) – As & Fe
Delnite Mineralogy - Pyrite

Uncovered tailings

Covered tailings (surface)
Metal Accumulation (3 – 5 years)

- No trend of increasing metal levels in the biosolids cover (from underlying tailings) observed.

- No trend of metal accumulation in crops observed.
Glencore - 2011
Glencore – Spring 2014
Glencore Fall 2014
Glencore – 2014

GroBark compost + N-Viro Soil biosolids
Other Examples

- Glencore Kidd Creek (Timmins) – black muck cover amended with mun. biosolids (Toronto)
- Kamkotia (Timmins) – considering mun. biosolids (Toronto) to help reclaim areas where tailings removed
- More to come…
Past and Current Research

**Goals**
- Beneficial reuse of wastes
- Diverting organics from landfill
- Advancing mine reclamation (productive land use)

**Consultation**
- City of Toronto
- Vale
- Glencore
- BHP Billiton
- Barrick

**Thick (1m) Covers**
- Corn
- Canola
- Switchgrass
- Sunflower
- Willow

**Thin covers**
- Canola
- Switchgrass
- Willow
- Sunflower
- Big Bluestem

**GMGE 2006-2012**

**BIOCHAR**

**Feasibility Study**
- Currently not economically feasible

**Signature project**

**Impact of C-rich amendments on mine stability 2013-2016**

- Impact of Covers
  - Geochemical
  - Microbes

- Characterization
  - Feedstock
  - Temperature
  - Residence time

- Potential Uses
  - Soil amendment
  - Metal sorption
  - Reprocess tailings
  - Alternative binders

**Glencore**
- 5 ha covered
- 10 ha in 2 years
- 96 ha total

**Vale**
- ~3 ha

**Compost + Mun. biosolids**
- GroBark/N-Viro

**Municipal biosolids**
- Toronto
Science Policy Objectives:

- Advance mine reclamation by reuse of organic wastes
- Establish long term agri-energy land use on tailings
- Improve reclamation options for tailings (i.e. contribute to social license)
- Provide scientific data that documents characteristics of novel by-products (e.g. biochar)
  - How can it be used in the mining industry?
  - Can it be altered to improve metal adsorption?
  - Improve marketability of products for mining
- Potential carbon storage in tailings
Biofuel Production

Pyrolysis

Dry Biomass

250°C
- Depolymerization
- Am. C

350°C
- Polyaromatic sheets of graphene grow

600°C

Gas

Bio-oil

Char (20 – 35%)
Impact of C-rich amendments on the long-term stability of mine wastes (2013-2016)

Biochar
- Characterization
- Potential uses
  - Soil amendment
  - Metal sorbent
  - Reprocess tails

Impact of Covers
- Post-evaluation GMGE
Team: 8 CMIN scientists + …

Collaborators

- Ag Canada
- Purdue U
  - *Ph. D. student*
- McGill U
  - *Ph. D. student*
- Others:
  - NRC, EC, CanmetENERGY

Industry Stakeholders

- Abri-Tech Inc.
- Airex Inc.
- Pyrovac
- Basques
- Vale Inc.
Soil amendment
- As a source for stable C and nutrient carrier
- Next phase for CMIN: scaling up to experiments in growth chamber
- Purdue received $260K grant for investigating the reclamation of coal spoils in Indiana (USA)

Metal sorbents
- Testing ways to make biochar more effective metal sorbents (e.g. H$_2$O$_2$ treatment)
- Willow and poultry manure derived biochars were effective sink for Pb precipitation as pyromorphite => potential application currently being tested for polluted rice lands in Indonesia
Using a range of biochars derived from various feedstocks and pyrolysis conditions, we characterized their physico-chemical properties to select the most promising amendments for reclamation of acidic tailings.

…”a much needed study for all of us manufacturers”…
Impact of cover: Post-evaluation GMGE

- Results indicate improvement of “soil health” in the oxidized, acidic tailings:
  - increased pH, reduced metal mobility,
  - increased microbial activity and diversity of populations

- The study provides proof-of-concept to support new research in BMP for mine reclamation at national scale (Genomic proposal; B. Tisch)
General Conclusions

- The GMGE initiative has demonstrated the technical feasibility of establishing biofuel crops on tailings while diverting organic residuals from landfill.
- Tailings can be converted from strictly a liability to a profit generating operation that involves local communities.
- Availability of sufficient volumes of organic residuals and cost of establishing the growth medium (cover) remain obstacles to larger scale usage.
Next Steps

Goals
• Beneficial reuse of wastes
• Diverting organics from landfill
• Advancing mine reclamation (productive land use)

Consultation
• City of Toronto
• Vale
• Glencore
• BHP Billiton
• Barrick

Potential Uses
• Soil amendment
• Metal sorption
• Reprocess tailings
• Alternative binders

Impact of Covers
✓ Geochemical
✓ Microbes

Characterization
✓ Feedstock
✓ Temperature
✓ Residence time

Feasibility Study
• Currently not economically feasible

Quantify/Augment
C storage in tailings

Carbon in Tailings
• CFS
• IETS
• Universities
• NRC
• Mining Industry
• Biochar producers

Soil development

GMGE

BIOCHAR

Thick (1m) Covers
✓ Corn
✓ Canola
✓ Switchgrass
✓ Sunflower
✓ Willow

Thin covers
✓ Canola
✓ Switchgrass
✓ Willow
✓ Sunflower
✓ Big Bluestem

Glencore
✓ 5 ha covered
• 10 ha in 2 years
• 96 ha total

Vale
✓ ~3 ha

Municipal biosolids (Toronto)

Compost + Mun. biosolids (GroBark/N-Viro)
Considerations for Moving Forward

- Odor control when applying
- Collection/consolidation of organic residuals
- Manufactured soils
- Pharmaceuticals/organic content of residuals
- Interaction with tailings
- Sound science and demonstrations
- Work with regulators in these projects
Thank You!

btisch@nrcan.gc.ca