Biosolids and Greenhouse Gas Accounting

Sally Brown, Andrew Carpenter, Ned Beecher, Andrew Trlica and Kate Kurtz
Global Carbon Cycle

- Most C is in oceans and crust
- In terrestrial pools, soils store about 3x more carbon than atmosphere or biomass
- Yearly C emissions are ~1% of atmospheric pool
Short term carbon cycle - soils and plants

Energy from the sun is used to 'fix' atmospheric \( \text{CO}_2 \) via photosynthesis.

The fixed \( \text{CO}_2 \), in the form of plant matter, is used as food by a wide range of animals, including microorganisms.

A portion of the carbon remains fixed (soil organic matter, animal biomass) and the remainder decomposes aerobically and returns to the atmosphere as \( \text{CO}_2 \).
Magnitude of different cycles

![Bar chart showing annual exchanges of billions of tonnes of carbon. The categories are Plant growth, Plant decay, and Fossil fuel emissions. The chart shows a positive value for Plant decay, a negative value for Plant growth, and a small positive value for Fossil fuel emissions.]

- Plant growth: Negative value
- Plant decay: Positive value (60 billion)
- Fossil fuel emissions: Positive value (5.5 billion)
Focus
However, Land disturbance and Climate Change

From Lal, 2004
Wastewater treatment

• A much more engineered system than the bear in the woods
• But basically part of the short term carbon cycle
The human version of the short term carbon cycle
Wastewater treatment—biological/living process

Anaerobic digestion - Biosolids / stabilization
Biosolids

- Can impact the carbon cycle:
  - By making or using energy
  - By replacing products that require energy to produce
  - By replacing products that emit GHGs
  - By emitting gasses other than CO2
  - By sequestering carbon
Biosolids GHG spreadsheet calculator tool
Brown et al, 2010 ES&T

• Andrew Carpenter, Northern Tilth
• Ned Beecher, NEBRA

• Funded by the Canadian Council Ministers on the Environment
• http://www.ccme.ca/ourwork/waste.html?category_id=137
### Combustion (incineration, thermal oxidation)

<table>
<thead>
<tr>
<th>Unit Processes &amp; Inputs</th>
<th>Inputs &amp; Daily Emissions</th>
<th>Default Input (Optional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids Input to incinerator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity (Mg/day-wet)</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Solids content (%)</td>
<td>25.0</td>
<td></td>
</tr>
<tr>
<td>Quantity (Mg/day-dry)</td>
<td>25.0</td>
<td></td>
</tr>
<tr>
<td>Is sludge digested prior to incineration?</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Total nitrogen (% dry weight)</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Total phosphorus (% dry weight)</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>VS (% dry weight)</td>
<td>70.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Recovered energy to electricity (%)</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Recovered energy as heat (%)</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td>Disposition of ash - is it used to replace phosphorus fertilizer or in cement or brick?</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>Average high (freeboard) temperature of combustion (°C)</td>
<td>950</td>
<td>950</td>
</tr>
</tbody>
</table>

### Energy Balance

- Natural gas needed to evaporate in sludge (m³/day): 6.21
- Avoided gas use from recovered energy (m³/day): 9.017
- Total natural gas used (m³/day): 196
- CO₂ emissions from natural gas used (Mg/day): -0.37

### Electricity Use

- Electricity requirements of incinerator (kWh/day): 5,000
- Electricity generated (kWh/day): 0
- Net Electricity used (kWh/day): 5,000
- CO₂ emissions from electricity used (Mg/day): 0.91

### Other Emissions

- CO₂ emissions equivalents from released methane (Mg/day): 0.03
- N₂O emitted during incineration (Mg/day): 0.064
- N₂O emission adjustment for SNCR based on urea (Mg/day): 0.000
- N₂O emission adjustment for moisture content of sludge (Mg/day): -0.032
- CO₂ emissions from released N₂O (Mg/day): 9.92

### Cement Replacement Value

- CO₂ replacement value from cement manufacture (Mg CO₂/day): 0.00

### Fertilizer Off-set Credits

- From phosphorus applied to soil (Mg CO₂/day): 0.00

### Biomass Combustion

- CO₂ Emissions equivalents from burning sludge (Mg/day): 35.93

### CO₂ Equivalents (Mg/year)

- Scope 1: 3.825
- Scope 2: 3.31
- Scopes 1 & 2: 3.825

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- Storage
- Conditioning/thickening
- Aerobic/anaerobic digestion
- Landfill disposal
- De-watering
- Thermal drying
- Alkaline stabilization
- Combustion
- Land application
- Transportation
Emissions Debits
- CO₂ - Scope 1 - gas and oil combustion
- CO₂ - Scope 2 - electricity use
- CO₂ - Scope 3 - polymer use and lime use
- CH₄ - methane emissions
- N₂O - nitrous oxide emissions

Emissions Credits
- CO₂ - Scope 1 - gas and oil combustion, carbon sequestration
- CO₂ - Scope 2 - electricity use
- CO₂ - Scope 3 - polymer use, lime use, fertilizer replacement, cement replacement
Debits for:
- CO₂ Scope 1 - gas and oil combustion
- CH₄ emissions
- N₂O emissions

Credits for:
- CO₂ Scope 1 - avoided gas and oil combustion, carbon sequestration
- CO₂ Scope 3 – avoided fertilizer use, avoided cement manufacture
First – not discussed
Drying- Centrifuge

- Centrifuge
- Higher % solids
- Much higher energy use
- 0.04-0.2 kWh/m³ wet
- Higher emissions from energy use

- Belt filter press
- Lower % solids
- Much lower energy use
- 0.004-0.01 kWh/m³ wet
Polymer

- 23 Mg $CO_2$ per Mg polymer
- Average use of 5 kg per dry Mg biosolids
- 50 kg $CO_2$ per dry Mg biosolids to aid in dewatering
## Tale of two cities

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Population</th>
<th>GHG Emissions for Electricity Generation</th>
<th>Treatment processes</th>
<th>End use/disposal</th>
<th>GHG Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>g CO₂e/kWh</td>
<td></td>
<td></td>
<td>Mg CO₂e/100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mg CO₂e/100</td>
<td></td>
<td></td>
<td>Mg dry solids</td>
</tr>
<tr>
<td>AN, Quebec</td>
<td>330,000</td>
<td>10</td>
<td>Rotary press dewatering</td>
<td>Incineration/heat recovery</td>
<td>1.48</td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>VA, British Columbia</td>
<td>980,000</td>
<td>20</td>
<td>Anaerobic digestion</td>
<td>Restoration land application</td>
<td>-0.23</td>
</tr>
<tr>
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</tbody>
</table>

Centrifuge dewatering

Ash recycling

Centrifuge dewatering
VA- Biosolids to land reclamation sites
>400 km round trip haul
VA summary

[Diagram showing CO₂ per dry Mg biosolids against VA, with categories for Electricity, Transport, CH4 + N2O, Carbon sequestration, and Fertilizer offset.]
Low $\text{CO}_2\text{e}$ for Electricity
AN summary
Gasses other than $CO_2$ can have a huge impact

$CH_4 - 21.23 \times CO_2 \quad N_2O = 296 \times CO_2$

Emissions of 1.5-6.4 kg $N_2O$ per dry Mg biosolids

0.44 - 1.9 Mg $CO_{2eq}$ per dry Mg

(Suzuki et al., 2003)
AN - energy versus fugitive emissions

Increasing burn temperature will decrease $\text{N}_2\text{O}$ emissions and result in a carbon neutral program
For some factors—high level of uncertainty Model uses conservative assumptions
N$_2$O for model- from literature
Preliminary studies at UW

- Biosolids added to turf in the greenhouse
- Surface application of Class A cake
- Sandy soil
- Clay soil
Higher $N_2O$ from biosolids
Model also includes -Landfill- Class B Disposal and daily cover

• **Credits**
  - Carbon storage

• **Debits**
  - Transport
  - Methane emissions
  - Nitrous oxide emissions
Landfill emissions

- Methane
- N2O
- Carbon storage
Landfill- Final cover
Akin to an agricultural use

• **Class A dry material**
  – Used at final surface
  – Used as a soil material
Different picture

![Bar graph showing Mg Dry Biosolids](image)

- **Transport**: Small positive value
- **Methane**: Small positive value
- **N2O**: Small positive value
- **Carbon Storage**: Large positive value
- **Fertilizer Offsets**: Large positive value
Comparison - disposal versus land application MWRDGC
Terminal Island Renewable Energy

"Terminal Island is setting the green standard for innovation, clean energy and renewable power nationwide"

Some things to consider

- Controlled anaerobic digestion with energy capture versus deep well injection?
- High level of uncertainty on fate and quantity of $\text{CH}_4$ produced underground
- There may be/are reasons to do this
- GHG balance for land application is a more robust source of credits
Conclusions

• Biosolids can be a significant source of GHG credits/credits
• Transport is of minimal importance
• Importance to use conservative, well documented default values
• Understanding and minimizing fugitive gas emissions is critical