Greenhouse Gas (GHG) Emissions from Wastewater Treatment and Biosolids Management

Ned Beecher
North East Biosolids and Residuals Association

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Photo: BioCycle
Presentation Outline

- Quick overview of wastewater treatment and biosolids management
- What are the potential greenhouse gas (GHG) emissions from these processes?
- Mitigating GHG emissions
  - Energy efficiency
  - Optimize processes to keep them aerobic
  - Offset fossil fuel use by extracting energy from biosolids.
  - Sequester captured carbon (C).
Why we have wastewater treatment

Nashua River, 1960s

Slide courtesy of NHWPCA / George Neill
Nashua River, 1980s
Manchester, NH – state’s largest WWTP

Slide courtesy of NHWPCA / George Neill
Biological treatment is the norm.

Microorganisms

Air is bubbled through the wastewater to help microorganisms thrive; pH and temperature are also controlled.

Middlebury, Vermont
Solids are separated out in clarifiers.
Solids are treated, dewatered…
…and must be managed…

…creating biosolids
Wastewater treatment uses energy. Biosolids can provide energy and offset greenhouse gas emissions.

**biosolids**: plural noun: organic matter recycled from sewage, especially for use in agriculture

What happens with U. S. biosolids?

Biosolids Use and Disposal Practices
2004 U.S. Totals

- Beneficial Use: 49%
- Disposal: 45%
- Other: 6%
Percent Biosolids Beneficially Used by State, 2004

The map shows the percent of biosolids beneficially used by state in 2004. The color scheme indicates different percentages, ranging from 0% to 100%. States are color-coded based on the percentage of biosolids used beneficially, with different shades of green representing varying levels of usage. The legend on the right provides a key to the color scheme, with each shade corresponding to a specific percentage range.

For example, states in the darkest green shade indicate a 100% beneficial use of biosolids, while those in very light green indicate 0% to 9% use. The map provides a visual representation of the distribution and extent of biosolid usage across the United States for the specified year.
New England & Quebec Biosolids Use & Disposal 2004

- QC: Beneficial Use: 20%, Disposal: 80%
- VT: Beneficial Use: 40%, Disposal: 60%
- NH: Beneficial Use: 60%, Disposal: 40%
- ME: Beneficial Use: 80%, Disposal: 20%
- MA: Beneficial Use: 60%, Disposal: 40%
- RI: Beneficial Use: 20%, Disposal: 80%
- CT: Beneficial Use: 0%, Disposal: 100%

Other or unknown categories are not shown.
Land application (41% of U.S. biosolids)

NH farm sites
The darker green areas of these grass hay fields have been fertilized with bulk Class B biosolids.
Land reclamation (3% of U.S. biosolids)

Central MA former gravel pit, 2006

Boston Harbor Islands, 2004
It’s effective...

a NH gravel pit 2 years after reclamation

1 year after reclamation
Composting

Merrimack
It’s effective in horticulture & landscaping…

The Great Lawn in New York’s Central Park is growing on Merrimack, NH biosolids compost.
Dried biosolids

GLSD, Massachusetts (includes wastewater from Salem); Boston also makes dried biosolids pellets
Dried biosolids are effective…

...some are used right close to home...

Castle Island, South Boston

The Esplanade along the Charles River is fertilized with Bay State Fertilizer.
Biosolids can provide energy (but incineration is not the efficient way)

Biosolids pellets are burned in cement kiln,
(Wikipedia photo)

Minnesota (photo courtesy Metropolitan Council)
Biosolids can provide energy  
(digestion is efficient)

Nashua:

- Anaerobic digester reduces biosolids volume and cost by > 50%.
- Costs for biosolids use reduced by ~ $1 million /yr.
- Electricity produced from burning biogas saves the plant an estimated $10,000 / month.
- Greenhouse gas benefits…
Talking of greenhouse gases...
Waste management = small %

(wastewater treatment = even smaller %)

Figure 8-1

2.3% of all emissions; wastewater treatment = 1/4 of that

EPA, 2007
CO₂ (mostly from energy use) is most notable GHG

WWTPs use lots of energy (= CO2 emissions)

- Wastewater treatment uses 3% of electricity in U. S. (EPA)
- In any city, this percentage is higher – up to 20%
- Lots of room for more energy efficiency and reducing CO2 emissions (current focus)
BUT… CH4 and N2O are also BIG for WWTPs

Global Warming Potential (GWP)

- $\text{CO}_2 = 1$
- $\text{CH}_4 = 21 \text{ CO}_2\text{e} \text{ (or 25 per latest IPCC 4th assessment)}$
- $\text{N}_2\text{O} = 310 \text{ CO}_2\text{e} \text{ (or 296 per latest IPCC)}$

- But over < 100 years, methane has higher GWP: $\sim 72 \text{ CO}_2\text{e}$
- Curbing these emissions now can provide “bridge” to low-C energy
Potential GHGs from on-site (septic) systems

- EPA estimates 75% of CH4 from wastewater treatment comes from septic systems (anaerobic tanks)
  - Questionable assumption; scant research
  - Does covering soil oxidize CH4?
  - Water Environment Research Foundation current study

- Most NH septage goes to WWTPs
  - Adds to solids - and GHG - production there
  - Some land applied (minimal GHG losses)
Potential GHG emissions from WWTPs & biosolids

- **Debits:**
  - CO2 from fossil fuel & electricity use
    - Direct & indirect (e.g. in polymers, lime)
  - CH4 from anaerobic wastewater or biosolids
  - N2O from near-anaerobic materials & combustion

- **Credits** (all are from how biosolids are managed):
  - Energy from biosolids
  - Offsetting fertilizer, peat, and lime use
  - Sequestering C

Remember...any CH4 or N2O are especially significant!
Typical Wastewater Treatment Plant

Source: Northwest Biosolids Management Association
Mitigating GHGs at WWTPs

1. Energy efficiency (VSD pumps, fine-bubble, etc.)
2. Optimize processes to keep them aerobic (assess & avoid CH4 & N2O losses).
3. Offset fossil fuel use by extracting energy from biosolids.
4. Sequester captured carbon (C).
Portfolio Manager

www.energystar.gov/benchmark

• EPA energy benchmarking system
• Now has module for WWTPs
• Compares a WWTP to similar plants
• Tracks energy efficiency improvements
Extracting energy: Nashua is a leader!
(digestion is most efficient)

**Nashua:**

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- Electricity produced from burning biogas saves the plant an estimated $10,000 / month.
- Greenhouse gas benefits…
Sequestering C = less CO$_2$ in atmosphere

- “Soils can contain as much as or more carbon than living vegetation. For example, 97 percent of the 335 billion tons (304 billion metric tonnes) of carbon stored in grassland ecosystems is held in the soil” (Amthor et al, Oak Ridge National Lab, 1998, as quoted at http://www.sustainablesites.org).

- “Some cultivated soils have lost one-half to two-thirds of the original SOC* pool ….The soil C sequestration is a truly win–win strategy. It restores degraded soils, enhances biomass production, purifies surface and ground waters, and reduces the rate of enrichment of atmospheric CO$_2$ by offsetting emissions due to fossil fuel” (R. Lal, Ohio State, 2004).

*soil organic carbon
Biosolids, manures, & compost have “C” for soils…

- Compost food waste
- Compost yard trimmings
- Manures / biosolids

Return them to soils!
Soil C after 10 years of gardening

Slide courtesy of Sally Brown, PhD
Univ. of WA
Soil C after site reclamation
Highland Valley Copper, BC

Slide courtesy of Sally Brown, PhD
Univ. of WA
Highland Valley, BC after 6-8 years

Slide courtesy of Sally Brown, PhD
Univ. of WA
Benefits of applying biosolids, etc. to soils
(Univ. of WA study: across all sites)

Slide courtesy of Sally Brown, PhD
Univ. of WA
Other benefits of biosolids use...

- Replacing chemical fertilizers
  - ~ 4 kg CO$_2$ / kg N (Recycled Organics Unit, 2006)
  - ~ 2 kg CO$_2$ / kg P (Recycled Organics Unit, 2006)
- Improved soil tilth / workability = less fuel for working soil
- Improved water holding capacity & infiltration (less runoff)
  (Not to mention replacing peat….and irrigation needs… and….)
### Life Cycle Analysis of solids options
Adapted from Murray et al., 2008

<table>
<thead>
<tr>
<th>Treatment</th>
<th>End use</th>
<th>Total economic cost</th>
<th>GWE* Mg CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dewatering</td>
<td>landfill</td>
<td>$26,000,000</td>
<td>380</td>
</tr>
<tr>
<td>Lime stabilization land application</td>
<td></td>
<td>$35,000,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Anaerobic (no lime) land application</td>
<td></td>
<td>$31,000,000</td>
<td>– 11,000</td>
</tr>
<tr>
<td>Anaer (no lime) + heat cement</td>
<td></td>
<td>$50,000,000</td>
<td>– 4,100</td>
</tr>
<tr>
<td>FBC incineration (gas) brick/cement</td>
<td></td>
<td>$190,000,000</td>
<td>65,000</td>
</tr>
</tbody>
</table>

*Economic cost* data are reported for a 20 year time horizon with 6% discount rate and include environmental externalities.

*GWE = global warming effect*

*alt means if land application is not an option*
NEBRA Study (2008):
Biosolids Management Options at Merrimack, NH

Report available at www.nebiosolids.org
Results

<table>
<thead>
<tr>
<th>Operation</th>
<th>kWh equivalent / dry ton solids</th>
<th>CO2 Equivalent Emissions (Mg / year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURRENT COMPOSTING</td>
<td>735</td>
<td>1529</td>
</tr>
<tr>
<td>UPGRADED COMPOSTING</td>
<td>568</td>
<td>1094</td>
</tr>
<tr>
<td>LANDFILLING AT ROCHESTER, NH</td>
<td>261</td>
<td>3,754</td>
</tr>
</tbody>
</table>

(Energy use does not necessarily equate with GHG emissions.)
Results: CO$_2$e emissions
BEAM: Comparing biosolids management scenarios
(each scenario includes thickening, de-watering and transport)

“Methane avoidance”

Energy recovery
Cold wet climate

800°C
25% solids
No recovery

900°C
30% solids
Energy recovery

Using virgin lime
**if recycled lime
→ total to -211**

65% heat
30% elect.
1% fugitive

Slide courtesy of Andrew Carpenter, Northern Tilth
Thanks for... your invitation, your attention, & your comments.

ned.beecher@nebiosolids.org
603-323-7654

Presentation available at:
www.nebiosolids.org
Under “Resources and Links,” choose greenhouse gas page.
Sewage sludge must be managed. There are 3 options; all present some risks. When trying to set policy on a complex matter like what to do with sewage sludge, it helps to look at what major expert scientific reviews found.

In 1996, the nation’s premier scientific body, the National Academy of Sciences (NAS), reviewed biosolids recycling and concluded:

“In summary, society produces large volumes of treated municipal wastewater and sewage sludge that must be either disposed of or reused. While no disposal or reuse option can guarantee complete safety, the use of these materials in the production of crops for human consumption, when practiced in accordance with existing federal guidelines and regulations, present negligible risk to the consumer, to crop production, and to the environment.”
An NAS 2002 review found:

“There is no documented scientific evidence that the Part 503 rule has failed to protect public health. However, additional scientific work is needed to reduce persistent uncertainty about the potential for adverse human health effects from exposure to biosolids. There have been anecdotal allegations of disease, and many scientific advances have occurred since the Part 503 rule was promulgated. To assure the public and to protect public health, there is a critical need to update the scientific basis of the rule to (1) ensure that the chemical and pathogen standards are supported by current scientific data and risk-assessment methods, (2) demonstrate effective enforcement of the Part 503 rule, and (3) validate the effectiveness of biosolids management practices.”

This research is ongoing; no findings of great risk. The risks being studied are far lower than addressed risks such as cholera, heavy metals, dioxins…

Benefits of biosolids use on land are well documented.