Estimate of United States GHG Emissions from Wastewater

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Outline

- Methane from Domestic Wastewater
  - GP factor
  - septic tanks
- Methane from Industrial Wastewater
  - meat and poultry, pulp and paper, fruits, vegetables, and juices
- $\text{N}_2\text{O}$ from wastewater
  - additional nitrogen loading
  - direct emissions
Methane from Domestic Wastewater

\[ \text{CH}_4 = \text{Population} \times \text{BOD/capita} \times \text{MCF} \times \text{EF} \]

- BOD = organic content in terms of Biological organic demand
- MCF = Percent of BOD$_5$ that is anaerobically digested
Methane from Domestic Wastewater

- Revised IPCC Emission Factor
- Revised Country specific MCF: 16.5%
  - inclusion of septic tanks:
    • 25% of US population
    • 50% treated anaerobically
  - revision of WWTP TA:
    • 75% of population
    • 5% treated anaerobically
Industrial wastewater treatment

- Current nitrogen measurements = negligible
- Potential for cost-effective mitigation for methane

Treatment:
Organic matter (BOD/COD)
- Soluble / insoluble
- Aerobic / anaerobic conditions
- Accidentally / deliberately managed under anaerobic conditions

Methane
Industrial wastewater: Methodology

For each evaluated industry:

\[ CH_4 \text{ emissions} = P \times O \times D \times TA \times EF \ (\text{grams/yr}) \]

Where:

- \( P \) = production (tons of product/yr);
- \( O \) = outflow (m\(^3\)/ton);
- \( D \) = average organic loading (grams organic COD/m\(^3\));
- \( TA \) = factor to express which part of organic COD is prone to organic degradation;
- \( EF \) = emission factor (0.25 gram CH\(_4\)/gram COD).
TA

- often expert judgment.
- TA = 1.0 for anaerobic lagoons and
- TA = 0.0 for most other (aerobic, chemical, and physical) processes.

Settling ponds may have anaerobic zones or pockets, Sludge may be anaerobic
Top Industry Sources

Step 1: Evaluate the industry sectors in the country that are believed to produce large volumes of organic wastewater.

- Meat and poultry: anaerobic lagoons;
- Pulp and paper industry: lagoons
- Vegetables, fruits and juices industry: lagoons

Organic chemicals, plastics and resins, starch production, alcohol refining, dairy products, and textiles: unlikely sources.
Petroleum refining wastewater included elsewhere.
Meat and poultry processing

Wastewater treatment:
- screening, fat traps and dissolved air flotation,
- anaerobic lagoons

Assumed that 77% for TA
  • Note: Will be reviewed upon completion of surveys

COD and wastewater flow based on actual measurements.
Pulp and paper manufacturing

565 pulp and paper manufacturing facilities in the US

Wastewater treatment:
- Pre-treatment, solids removal,
- lagoons for storage, settling, and
- lagoons for biological treatment

Based on survey data:
- 42% of organics to secondary treatment and
- 25% of organics in secondary treatment lagoons are treated anaerobically
- BOD used because more reliable data
Fruits, vegetables, and juices
Processing

Wastewater treatment:
- screening, coagulation/settling and
- biological treatment (lagooning),
- effluent to municipal sewer

Assumed that 5% of wastewater organics degrades anaerobically.
Parameters used and CH$_4$ emissions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Meat &amp; poultry</th>
<th>Pulp &amp; paper</th>
<th>Fruits, juices, vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual production</td>
<td>Tons x 1000</td>
<td>38,000</td>
<td>144,367</td>
<td>37,900</td>
</tr>
<tr>
<td>WW Generation</td>
<td>(m$^3$/ton)</td>
<td>13</td>
<td>85</td>
<td>5.6</td>
</tr>
<tr>
<td>BOD</td>
<td>(g/l)</td>
<td>0.4</td>
<td>0.4</td>
<td>5</td>
</tr>
<tr>
<td>COD</td>
<td>(g/l)</td>
<td>4.1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>TA</td>
<td>(%)</td>
<td>77</td>
<td>10.3</td>
<td>5</td>
</tr>
<tr>
<td>CH$_4$ Emissions</td>
<td>Gg/yr</td>
<td>390</td>
<td>303</td>
<td>13.3</td>
</tr>
</tbody>
</table>
Nitrous Oxide from wastewater

- IPCC default methodology
  - human sewage only
  - effluent emissions only
- EPA revised methodology:
  - additional domestic nitrogen
  - co-discharged industrial nitrogen
  - direct emissions from treatment
**Table 2. Estimate of the components of total (dissolved and suspended) solids in wastewater**

<table>
<thead>
<tr>
<th>Component</th>
<th>Range</th>
<th>Typical</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic wastes:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feces (solids, 23 percent)</td>
<td>0.07–0.15</td>
<td>0.09</td>
<td>9</td>
</tr>
<tr>
<td>Urine (solids, 3.7 percent)</td>
<td>0.09–0.15</td>
<td>0.11</td>
<td>11</td>
</tr>
<tr>
<td><em>Total Feces and urine</em></td>
<td></td>
<td>0.20</td>
<td>20</td>
</tr>
<tr>
<td>Ground food wastes</td>
<td>0.07–0.18</td>
<td>0.10</td>
<td>10</td>
</tr>
<tr>
<td>Sinks, baths, laundry, other wash waters</td>
<td>0.13–0.22</td>
<td>0.18</td>
<td>19</td>
</tr>
<tr>
<td>Toilet (incl. paper)</td>
<td>0.03–0.06</td>
<td>0.04</td>
<td>4</td>
</tr>
<tr>
<td>Total from domestic wastes¹</td>
<td>0.41–0.80</td>
<td>0.52</td>
<td>54</td>
</tr>
<tr>
<td>Industrial wastes:</td>
<td>0.33–0.88</td>
<td>0.44</td>
<td>46</td>
</tr>
</tbody>
</table>

¹ adapted from Metcalf and Eddy (1991), Table 5-3
² excluding water softeners
Additional Domestic Nitrogen Loading

- All domestic nitrogen loading = 1.4 times human sewage nitrogen only
  - data not available for every year so 1.4 factor used

- Industrial co-discharge
  - Average amounts: industrial = 1.25 times human sewage nitrogen only
  - data not available every year

- Overall 1.75 times human sewage methodology
Direct emissions from WWTPs

- Current IPCC default method only for effluent
- Direct estimates from treatment plants
  - emission factor (4 g N$_2$O/person.year)
    - based on secondary treatment measurements (Czepiel, 1995)
    - does not include N$_2$O emissions from sewers and primary treatment.
- Small part of wastewater inventory:
  - 1-2 Gg/year, human sewage = 26 Gg in 1999
Conclusions and Uncertainties

- Best data found through surveys for effluent rule making
- % of national CH$_4$ estimates.
- Methane emissions from the fruits, vegetables, and juices category are insignificant.

Uncertainties
- heterogeneous nature of wastewater treatment
- degree to which anaerobic degradation occurs