Philippines GHG Emissions: Waste Sector

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World Greenhouse gas emissions by sector

- **Transportation**: 13.5%
  - Road: 9.9%
  - Air: 1.6%
  - Rail, Ship & Other Transport: 2.3%
- **Electricity & Heat**: 24.6%
  - Residential Buildings: 9.9%
  - Commercial Buildings: 5.4%
  - Iron & Steel: 3.2%
  - Aluminium/Non-Ferrous Metals: 1.4%
  - Machinery: 1%
- **Other Fuel Combustion**: 9%
- **Industry**: 10.4%
  - Other Industry: 5.0%
  - Textile Mills: 1.6%
  - Other: 1.2%
- **Fugitive Emissions**: 3.9%
- **Industrial Processes**: 3.4%
- **Land Use Change**: 18.2%
  - Deforestation: 18.3%
  - Afforestation: -1.5%
  - Reafforestation: -0.5%
  - Harvest/Management: 2.5%
  - Other: -0.6%
  - Agricultural Energy Use: 1.4%
  - Agriculture Soils: 6%
- **Agriculture**: 13.5%
  - Livestock & Manure: 5.1%
  - Rice Cultivation: 1.5%
  - Other Agriculture: 0.9%
  - Landfill: 0.3%
  - Wastewater, Other Waste: 1.7%
- **Waste**: 3.6%

All data is for 2000. All calculations are based on CO₂ equivalents, using 100-year global warming potentials from the IPCC (1996), based on a total global estimate of 41 755 MtcO₂ equivalent. Land use change includes both emissions and absorptions. Dotted lines represent flows of less than 0.1% percent of total GHG emissions.

Rapid urbanization is positively correlated with the increase in the consumption and production of goods.

Leads to an increase in the volume of waste generated by the commercial, domestic, and industrial sectors.

Releases greenhouse gases in the atmosphere that could interfere with our climate systems → methane, carbon dioxide and nitrous oxide.
Solid wastes, industrial and domestic wastewater, and human sewage are the sources of greenhouse gas emissions for the waste sector. For the year 2000, the waste sector released 11,556 Gg of CO$_2$ to the atmosphere. Approximately 47% of the total emissions come from solid waste which generated 259 Gg of CH$_4$ or 5,439 Gg CO$_2$. 

Waste Sector
Subsectoral Contributions

- Solid Waste: 47%
- Municipal Wastewater: 32%
- Industrial Wastewater: 12%
- Human Sewage: 9%
SOLID WASTE

• Increase in the production of solid waste is generally proportional with the population.

• The daily generation of waste by a Filipino ranges from 0.3 to 0.7 kilos of garbage depending on his economic status.

SOLID WASTE DISPOSAL

• Treatment and disposal of solid waste produces significant amounts of methane (CH$_4$)

• CH$_4$ produced at solid waste disposal sites (SWDS) contributes 3-4% to the annual global anthropogenic greenhouse gas emissions (IPCC, 2001)

• SWDS also produce biogenic carbon dioxide (CO$_2$), non-methane volatile organic compounds (NMVOCs), nitrous oxide (N$_2$O) nitrogen oxides (NO$_x$), carbon monoxide (CO) although CH$_4$ is the primary greenhouse gas in SWDS
SOLID WASTE DISPOSAL

• Conversion of degradable material in waste to methane and carbon dioxide is complex
• The series of equations below is a simplified version of the DOC transformation to CO₂ and CH₄ (methanogenesis):

  Organic matter $\rightarrow$ H₂, CO₂, & carboxylic acids
  CO₂ + 4H₂ $\rightarrow$ CH₄ + 2H₂O
  CH₃COOH $\rightarrow$ CH₄ + CO₂
Most of the calculations were based on the 1994 inventory process, the JICA-sponsored research on urban waste management, and the ADB-sponsored Metro Manila Solid Waste Management Project.
In many countries waste management has changed much over the last decade:

- waste minimization and recycling/reuse,
- policies to reduce the amount of waste generated
- alternative waste management practices
- landfill gas recovery
- Implementation of R.A. 9003 (January 2001)
Methodology

• Three levels to estimate the CH4 emissions (highly dependent on the data available):
  ▪ **Tier 1**: uses default activity data and default parameters
  ▪ **Tier 2**: uses some default parameters, and good quality country-specific data on current and historical waste disposal at SWDS
Methodology

• Three levels to estimate the CH4 emissions (highly dependent on the data available):
  ▪ **Tier 3**: uses country-specific activity data, and nationally developed key parameters:
    - Half-life
    - Methane Generation Potential
    - Degradable organic content (DOC) in the waste
    - Fraction of DOC that decomposes
**CH$_4$ Estimation Models**

- Two models to estimate CH$_4$ emissions from SWDS:
  1. Mass Balance Approach
  2. First Order Decay (FOD) Method
CH$_4$ Estimation Models

- Mass Balance Approach
  - Used in the 1994 Philippine inventory
  - Does not distinguish between various types of disposal sites (e.g. open dump or sanitary landfill)
  - Strongly discouraged because it produces inaccurate estimates of annual emissions (IPCC, 2006)
CH$_4$ Estimation Models

• First Order Decay Model
  ▪ Degradable organic component (DOC) decays slowly throughout a few decades
  ▪ Requires historical waste disposal data over a time period of 3-5 half lives
    ▪ Half lives vary from a few years to several decades
    ▪ Good practice to use disposal data for at least 50 years (1950 – 2000)
CH$_4$ Estimation Models

Pertinent Equations

1. DDOC$m$ Accumulated in the SWDS

$$\text{DDOC}ma_T = \text{DDOC}md_T + (\text{DDOC}ma_{T-1} \cdot e^{-k})$$

Where:

- $\text{DDOC}ma_T = \text{DDOC accumulated at the end of the year } T$
- $\text{DDOC}ma_{T-1} = \text{DDOC accumulated in the previous year}$
- $\text{DDOC}md_T = \text{DDOC deposited in the year } T$
Pertinent Equations

2. DDOCe decomposed at the end of the year

\[ DDOCe \, decomp_T = DDOCe_\sigma_{T-1} \cdot (1-e^{-k}) \]

Where:

- \( DDOCe_\sigma_{T-1} = DDOC \) accumulated in the previous year
- \( DDOCe \, decomp_T = DDOC \) decomposed at the end of the year
- \( k = \) reaction constant
CH$_4$ Estimation Models

Pertinent Equations

3. CH$_4$ generated from DDOCm

\[ CH_4\ generated_T = DDOCm\ decomp_T \times F \times \frac{16}{12} \]

Where:

- \( CH_4\ generated_T \) = amount of CH$_4$ generated from decomposable material
- \( DDOCm\ decomp_T \) = DDOC decomposed in year \( T \)
- \( F \) = fraction of CH$_4$ in generated landfill gas
- \( \frac{16}{12} \) = molecular weight ratio CH$_4$/C
Using the IPCC Waste Model

- Incorporates the FOD Model
- Based on equations 1-3
- Data from 1950-2000 must be supplied
Using the IPCC Waste Model

• Requires the following data:
  - Urban Population
  - Waste per capita generation rate (kg/cap/year)
  - Percentage of waste that goes to different disposal sites
  - Percent composition of wastes that goes to the disposal sites
  - Industrial waste generation rate (Gg/$M GDP/yr),
  - Percent of industrial solid waste that goes to solid waste disposal sites
  - Amount of methane recovered
# Results

<table>
<thead>
<tr>
<th>Year</th>
<th>Methane (Gg)</th>
<th>Carbon Dioxide (Gg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994 (Mass Balance)</td>
<td>302.73</td>
<td>6,357.3</td>
</tr>
<tr>
<td>1994 (FOD)</td>
<td>307</td>
<td>6,447</td>
</tr>
<tr>
<td>2000 (FOD)</td>
<td>287</td>
<td>6,027</td>
</tr>
</tbody>
</table>
Solid Waste Subsector
GHG Inventory from Waste (Wastewater)

- Domestic/commercial and industrial sources
- Treatment: on site, centralized or directly disposed
  - Anaerobic treatment produces methane
  - May also be a source of CO$_2$ and N$_2$O
  - Differs between countries, between rural and urban areas
Factors affecting methane production

Wastewater Characteristics

– Methane generation potential: degradable organic material present
  • Parameters used
    – BOD (Biochemical Oxygen Demand)
    – COD (Chemical Oxygen Demand)
    – Higher BOD or COD means more methane generated
Factors affecting methane production

Temperature

• Methane production at 15°C and higher
  – Increase in temperature means rate of methane production increases
  – Below 15°C: Fermentation and thus CH4 production is negligible and lagoon serves as a sedimentation tank
Factors affecting methane production

BOD vs. COD

- **BOD** (Biochemical Oxygen Demand) concentration indicates only the amount of carbon that is aerobically biodegradable
  - less appropriate for determining the organic components in anaerobic environments
- **COD** (Chemical Oxygen Demand) measures the total material available for oxidation (both biodegradable and non-biodegradable)
- Reported COD/BOD ratios can be used to determine the COD if the BOD is known
Domestic Wastewater

• The greenhouse gas (GHG) generation potential of the wastewater is driven by the organic content of the wastewater stream (BOD) and the volume of wastewater.
Domestic Wastewater

Data needed:

1. Degradable organic component (DC) indicator in kg DC per 1000 persons per year. For domestic wastewater and sludge, BOD is the recommended DC indicator.

2. Country population in thousands

3. Fraction of BOD removed as sludge.
## Results

<table>
<thead>
<tr>
<th>Year</th>
<th>Methane (Gg)</th>
<th>Carbon Dioxide (Gg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic</td>
<td>46.02</td>
<td>966.47</td>
</tr>
<tr>
<td>Industrial</td>
<td>43.83</td>
<td>920.5</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic</td>
<td>307.43</td>
<td>6,456.03</td>
</tr>
<tr>
<td>Industrial</td>
<td>64.20</td>
<td>1,348.2</td>
</tr>
</tbody>
</table>
Domestic Wastewater Subsector

Net Annual Methane Emissions (Gg CH₄)

Year


302.209 308.313 314.541 320.897 327.379 333.992 340.740 347.622

Graph showing the increase in net annual methane emissions from 1999 to 2008.
Human Sewage Subsector

Data Requirements

- Per capita protein consumption
- National Population
- Amount of sewage applied to soils as sewage sludge

- National Statistical Information Center (NSIC)
- Department of Science and Technology - Food and Nutrition Research Institute (DOST- FNRI)
- Manila Water Co.
Nitrous Oxide Emissions from Human Sewage

Worksheet 6-4 Human Sewage, Sheet 1 of 1

1. Enter the per capita protein consumption in terms of kg/person/year in column A.

2. Enter the national population in column B.

3. Enter the fraction of nitrogen in protein in column C. The default value is 0.16 kg N per kg protein (IPCC, 1996).
4. In column D, the amount of sewage N produced (in kg N/yr) is calculated automatically by multiplying values in columns A, B and C.

5. Enter the amount of sewage N applied to soils as sewage sludge (in kg N/yr) in column E.

6. In column F, the net amount of sewage produced (in kg N/yr) is calculated by subtracting value in column D with value in column E (D - E).
7. Enter the emission factor EF in column G. The default value is 0.01 kg N2O per kg sewage–N produced (IPCC, 1996)

8. In column H, multiply together the values in columns F and G and the molecular conversion ratio, 44/28. Then convert this to Gg. This yields the total annual N2O emissions from human sewage (in Gg N2O).
Human Sewage Subsector

<table>
<thead>
<tr>
<th>Year</th>
<th>N₂O Emissions (Gg CH₄)</th>
<th>CO₂ Equivalent (Gg/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>1,084.80</td>
<td>3.50</td>
</tr>
<tr>
<td>2000</td>
<td>1,106.93</td>
<td>3.57</td>
</tr>
<tr>
<td>2001</td>
<td>1,129.51</td>
<td>3.65</td>
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<tr>
<td>2002</td>
<td>1,152.55</td>
<td>3.72</td>
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<td>2003</td>
<td>1,176.06</td>
<td>3.80</td>
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<td>2004</td>
<td>1,200.05</td>
<td>3.87</td>
</tr>
<tr>
<td>2005</td>
<td>1,224.53</td>
<td>3.95</td>
</tr>
<tr>
<td>2006</td>
<td>1,275.00</td>
<td>4.12</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

- In 2000, the emissions rose to 11,556 Gg CO$_2$e, a 63% increase compared to the 1994 emissions.

- The increase in industrial waste subsector is attributed to the increase in production industries and inclusion of untreated wastewater in the calculations.

- The increase in N$_2$O from human sewage could be attributed to the population growth.

- GHG emissions from municipal wastewater is due to the use of a new value for methane producing capacity constant (from 0.25 kg CH4/kg BOD to 0.6 kg CH4/kg BOD)

- The decrease in emissions for the solid waste is due to the change in estimation model from mass balance approach to FOD.
Sources of Data

Published Articles:


Metropolitan Manila Development Authority (MMDA), Metropolitan Solid Waste Management Office (2008). Ang Basura ng Metro Manila. Leaflet


Sources of Data


National Statistical Coordination Board (2003). *Balance Sheet of the Philippines*


Sources of Data (Website)

