Recent development on Japan’s inventories with regard to solid waste disposal

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Total GHG Emission from Japan

Emission from Waste Sector is 3~4% of Total.
Emission from SWDS is 12~24% of Waste Sector.
GHG emission from landfill sites has been **drastically reduced** by “Separation at Source”, “Intermediate Treatment (Incineration)” and “Semi-Aerobic Landfill”, which were originally introduced for improvement of public health and environment.
Waste in Japan

- Waste are classified into “municipal waste” and “industrial waste,” in keeping with Japanese regulations.
- Industrial waste contains 20 types of waste from business activities, provided for exclusively under the Waste Management Law.
- Household E-waste and end-of-life vehicles are separately treated and recycled by producers.
- Municipal waste is other waste to be treated by municipalities and is classified into “municipal solid waste,” such as garbage from households, and “human excrement (and sludge from johkasou)”.
- Wastewater and solid waste are treated separately.

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**Source of Waste**
- Household
- Commercial
- Office
- Waterworks, Sewage
- Construction
- Agriculture, Forestry, Fisheries
- Mining
- Manufacturing industry
- Energy industry
- Hospital

**Waste classification**
- Municipal solid waste
  - Domestic wastewater
    - Refrigerator, washing machine, air conditioner, television
  - Industrial wastewater
  - Hazardous waste
    - Combustion residues, organic sludge, inorganic sludge, waste oil, waste acid, waste alkali, waste plastics, waste paper, waste wood, waste textile, animal and plant residues, waste rubber, waste metal, glass and ceramics, mining waste, demolition debris, soot and dust, livestock waste, animal carcass
- Industrial solid waste
- Household E-waste
- End-of-life vehicles
MSW Stream at a Glance

Generation

- Metals, Paper & Glass
- Organics & Plastic
- Incombustibles (Ceramics, Plastic & Glass)

Recycling

- Combustibles
- Incombustibles
- Recycables
- (Packaging) Plastic

Incineration

- ca. 80%
- Ash
- Residue

Pyrolysis (Oil or Gas)
- Blast Furnace
- Coking

Landfill

Separation at Source

[ca. 50 million tonnes]
[ca. 6.5 million tonnes]
[ca. 8 million tonnes]
Composition of MSW (for combustible waste)

Are plastics included in combustible waste?

- Wet basis in around 1999

<table>
<thead>
<tr>
<th>City</th>
<th>Garbage (%)</th>
<th>Glass/Pottery/Stone (%)</th>
<th>Food (%)</th>
<th>Rubber/Leather/Plastics (%)</th>
<th>Wood/Splits/Straws/Grass (%)</th>
<th>Paper (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sapporo</td>
<td>46.3</td>
<td>38.1</td>
<td>26.6</td>
<td>31.3</td>
<td>26.6</td>
<td>46.3</td>
</tr>
<tr>
<td>Sendai</td>
<td>37.3</td>
<td>52.5</td>
<td>31.3</td>
<td>36.2</td>
<td>36.2</td>
<td>37.3</td>
</tr>
<tr>
<td>Tokyo (23 wards)</td>
<td>25.8</td>
<td>39.6</td>
<td>33.3</td>
<td>40.6</td>
<td>33.3</td>
<td>36.9</td>
</tr>
<tr>
<td>Nagoya</td>
<td>25.8</td>
<td>39.6</td>
<td>33.3</td>
<td>40.6</td>
<td>33.3</td>
<td>36.9</td>
</tr>
<tr>
<td>Kobe</td>
<td>25.8</td>
<td>39.6</td>
<td>33.3</td>
<td>40.6</td>
<td>33.3</td>
<td>36.9</td>
</tr>
</tbody>
</table>

- Yes: Include plastics
- No: Do not include plastics
MSW Statistics

✓ Data is obtained by measurement of every load. Municipalities, who are responsible to disposal, measure waste, recovered materials and its treated residues at the gate of plants and disposal sites.

✓ This statistical survey is yearly.

✓ The national government request for this data to prefectures.

✓ Waste composition data is not demanded for national statistics. However, municipalities occasionally estimate this for operation of plants and planning of waste management.
Industrial Waste Statistics

- Data is obtained by the sample method. Prefectures send questionnaires to generators who are responsible to disposal.
- This statistical survey is usually quinquennial. Timings of survey are different for prefectures.
- The national government request for summery of this data to prefectures.
- Betweenness is interpolated using generation units of 66 industrial sectors, which denominators are economic drivers, such as shipment value, number of employees, headage, etc.
- More detail mass flow of industrial waste streams is complemented by additional inquiry surveys and statistics from industries.
# Sub Categories for SWDS

<table>
<thead>
<tr>
<th>Category</th>
<th>Item</th>
<th>Mode</th>
<th>CH4</th>
<th>CO2</th>
<th>N2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal Solid Waste</td>
<td>Food (Garbage)</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Paper</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Wood</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Textile (made by Natural Fiber)</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Sludge (Nign Soil Treatment and Jokasou)</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Industrial Solid Waste</td>
<td>Food</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Paper</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Wood</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Textile (made by Natural Fiber)</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Sludge</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Other</td>
<td>Illegal Dumping</td>
<td>Anaerobic</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>Composting</td>
<td>Composting</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>
Method for Estimation

- First Order Decay (FOD) Model with Domestic Parameters (Tier. 3)

\[ E = \{ \sum (EF_{i,j} \times A_{i,j}) - R \} \times (1 - OX) \]

- \( E \): CH4 Emission from managed disposal sites (kg-CH4)
- \( EF_{i,j} \): Emission factor of degradable waste, \( i \) disposed to site with structure, \( j \) without incineration (kg-CH4/t)
- \( A_{i,j} \): Degraded waste of degradable waste, \( i \) degradable waste disposed to site with structure, \( j \) without incineration in a inventory year (t-dry)
- \( R \): CH4 recovery (t)
- \( OX \): Fraction of CH4 oxidation in cover soil (-)
Emission Factor

• $EF = \text{[Carbon Content]} \times \text{[Fraction of Gasification]} \times \text{[Methane Correction Factor]} \times \text{[CH4 Fraction in Landfill Gas]}

  - Carbon Content
  - Fraction of Gasification ($DOC_f$): 50%
  - MCF: anaerobic=1.0, semi-aerobic=0.5
  - CH4 Fraction: 50%

<table>
<thead>
<tr>
<th>Item</th>
<th>%-dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food (Garbage)</td>
<td>43.4</td>
</tr>
<tr>
<td>Paper</td>
<td>40.9</td>
</tr>
<tr>
<td>Wood</td>
<td>45.0</td>
</tr>
<tr>
<td>Textile</td>
<td>45.2</td>
</tr>
<tr>
<td>Sawage</td>
<td>40.0</td>
</tr>
<tr>
<td>Night Soil Treatment and Jokasou</td>
<td>40.0</td>
</tr>
<tr>
<td>Water Supply</td>
<td>7.5</td>
</tr>
<tr>
<td>Manufacture</td>
<td>45.0</td>
</tr>
<tr>
<td>Cattle Manure</td>
<td>40.0</td>
</tr>
</tbody>
</table>
Carbon Content

Set by the 9 types of waste

- **Kitchen garbage, Waste paper, Waste Woods**
  - Data sources: Result of analyses for MSW conducted by 5 cities in Japan
  - Set by averaging all data between 1990-2004
  - MSW data have been used for also ISW

- **Waste natural fiber textile**
  - Data sources: Carbon content of each natural fiber products data and domestic demand of each fiber
  - Set by averaging of carbon content in each year from 1990 to 2004

- **Sewage sludge**
  - Use the upper limit of default value presented in GPG2000 on ground of Japan’s domestic research results

- **Human waste sludge, Livestock waste**
  - Use the sewage sludge’s value in consideration with properties of waste

- **Waterworks sludge**
  - Intermediate results of measurements at several water purification plants in Japan has been used

- **Organic sludge from manufacturing industries**
  - Use papermaking industry’s value in view of data limitation
  - Paper sludge is the main organic sludge under papermaking industry and the carbon content were calculated by the cellulose’s carbon content
Landfill Types in Japan

Emissions from SWDS have been calculated under two types of landfill; semi-aerobic landfill and anaerobic landfill.

- **Semi-aerobic landfill**
  
  Regarding as semi-aerobic those sites which have leachate treatment facilities and subsurface containment structures.

- **Anaerobic landfill**
  
  Disposal sites where landfilling started before the 1977 joint order, and all coastal and inland water landfills are treated as anaerobic disposal sites.
Landfill types in IPCC GL

The “managed” landfill in Guidelines is classified to the “anaerobic landfill”.

Traditional Sanitary Landfill

- Permeable Top Cover
- High Water Table
- No or Incomplete Leachate Drain

Western Landfill

- Impermeable Top and Bottom Liner
- (Methane Recovery?)
- Minimize amount of Leachate
- Dry Tomb

Emission of polluted leachate will be extend over a long period of time.
Semi-Aerobic Landfill

Gas Ventilation System
(Porous pipes connecting to leachate drain)

Top Cover Soil
(Allowing rainfall penetration)

Waste Layer

Leachate Drainage System

Regulating Pondage
(Keep at low water level)

Go to Leachate Treatment Plant

Exchange of Air and LFG

Natural (passive) ventilation will be occurred by temperature difference between waste layer and outside air.

Aerobic decomposition of waste can improve quality of leachate and LFG emission.
Fraction of DOC that can decompose

Generally the amounts of DOC lost with the leachate are low (less than 1%) and can be neglected in the calculations. (2006 IPCC Guideline)

Is this explanation realistic in Asian Countries?
Activity

\[ W_i(T) = W_i(T - 1) \times e^{-k} + w_i(T) \]

\[ A_i(T) = W_i(T - 1) \times (1 - e^{-k}) \]

\[ k = \ln(2) / H \]

\( A_i(T): \) Degraded waste, \( i \) in a inventory year, \( T \)
\( W_i(T): \) Remained waste, \( i \) at disposal site in a inventory year, \( T \)
\( w_i(T): \) Disposed waste, \( i \) in a inventory year, \( T \)
\( k: \) Degradation rate (1/yr)
\( H: \) Half life of waste, \( i \)

\[ w_i = [\text{Degradable waste disposed}] \times [\text{Fraction of waste disposed to site with different structures}] \times [\text{Fraction of dry matter in waste, } i] \]
Activity

- Degradable waste disposed
  - Accounting amount of disposal waste other than flowing stream with incineration
## Activity

- **Fraction of dry matter in waste**

<table>
<thead>
<tr>
<th>Item</th>
<th>Dry matter content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td></td>
</tr>
<tr>
<td>Pre-Treated</td>
<td>25</td>
</tr>
<tr>
<td>MSW</td>
<td>30</td>
</tr>
<tr>
<td>ISW</td>
<td>80</td>
</tr>
<tr>
<td>Textile (Natural)</td>
<td></td>
</tr>
<tr>
<td>MSW</td>
<td>80</td>
</tr>
<tr>
<td>ISW</td>
<td>85</td>
</tr>
<tr>
<td>Sludge</td>
<td></td>
</tr>
<tr>
<td>Night Soil Treatment and Jokasou</td>
<td>Direct Disposal 15</td>
</tr>
<tr>
<td></td>
<td>Pre-Treated</td>
</tr>
<tr>
<td>Water Supply</td>
<td></td>
</tr>
<tr>
<td>Cattle Manure</td>
<td>Direct Disposal 16.9</td>
</tr>
<tr>
<td></td>
<td>Pre-Treated</td>
</tr>
<tr>
<td>Manufacture</td>
<td>Food Processing 77</td>
</tr>
<tr>
<td></td>
<td>Chemical</td>
</tr>
<tr>
<td></td>
<td>Pulp and Paper closed</td>
</tr>
</tbody>
</table>
Activity

• Fraction of waste disposed to site with different structures

<table>
<thead>
<tr>
<th>Category</th>
<th>Structure</th>
<th>1977</th>
<th>1990</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSW</td>
<td>anaerobic</td>
<td>100</td>
<td>64.2</td>
<td>45.3</td>
</tr>
<tr>
<td></td>
<td>semi-aerobic</td>
<td>0</td>
<td>25.8</td>
<td>54.6</td>
</tr>
<tr>
<td>ISW</td>
<td>anaerobic</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

• Half Life
  - Food: 3 years, Paper: 7 years, Textile (natural): 7 years, Wood: 36 years, Sludge: 3.6 years (default)

• Delay Time
  - 6 month
### Activity

**Activity for Emission from managed SWDS**

<table>
<thead>
<tr>
<th>Item</th>
<th>Degraded waste in a inventory year: 1,000 tonnes/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>517</td>
</tr>
<tr>
<td>Paper</td>
<td>1246</td>
</tr>
<tr>
<td>Textile (natural)</td>
<td>73</td>
</tr>
<tr>
<td>Wood</td>
<td>344</td>
</tr>
<tr>
<td>Sludge</td>
<td></td>
</tr>
<tr>
<td>Swage Treatment</td>
<td>297</td>
</tr>
<tr>
<td>Night Soil Treatment and Jokasou</td>
<td>51</td>
</tr>
<tr>
<td>Water Supply</td>
<td>192</td>
</tr>
<tr>
<td>Manufacture</td>
<td>363</td>
</tr>
<tr>
<td>Animal Manure</td>
<td>251</td>
</tr>
<tr>
<td>Total</td>
<td>3336</td>
</tr>
</tbody>
</table>
Other

- CH₄ Recovery
  - For one site

<table>
<thead>
<tr>
<th></th>
<th>unit</th>
<th>1990</th>
<th>1995</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFG Usage</td>
<td>km3N</td>
<td>1985</td>
<td>2375</td>
<td>1561</td>
</tr>
<tr>
<td>CH₄ Conc.</td>
<td>%</td>
<td>53.3</td>
<td>42.2</td>
<td>40.0</td>
</tr>
<tr>
<td>CH₄ Usage</td>
<td>km3N</td>
<td>1059</td>
<td>1003</td>
<td>624</td>
</tr>
<tr>
<td></td>
<td>GgCH₄</td>
<td>0.76</td>
<td>0.72</td>
<td>0.45</td>
</tr>
</tbody>
</table>

- Fraction of CH₄ oxidation in cover soil
  - 0
**Structures of MSW Stream**

**Western Countries**
- Waste → Collection → Mechanical Separation + Aerobic Treatment → Landfill → LFG recovery
- MBT (Mechanical-Biological Treatment)
- "Mechanical Separation" should be applicable to waste with low water content.

**Japan**
- Waste → Source Separation → Collection → Incineration → Landfill
- Paper, Metals, Glass, Plastic → Substantial reduction of organics
- Combustibles → Uncombustibles
- Few CH4 emission
- "Incineration" has been selected due to sanitation of waste with high water content.

**Asian Countries**
- Waste → Collection → Landfill
- "Resource" includes organic materials with high water contents for composting.
- Organics is still valuable resource
- Prolonged emission of CH4
- Incomplete reduction of organics
- Few CH4 emission
Issues on Estimation of MSW stream

✓ Waste mass data on authorized management stream can be estimated from account (monetary) data.
  ✓ Uncertainty will be depended on conversion from truck road to weight.
  ✓ Installation of treatment and resource recovery facilities before disposal will improve quality of SWDS and waste statistics.

✓ 3R activities including unauthorized resource recovery can significantly be change mass and composition of MSW.
  ✓ “How to estimate the unauthorized stream” is important research issue.
  ✓ “How to incorporate unauthorized activity to waste management” is important political issue.

✓ Better waste management will lead to better estimation and environment.
Co-benefit in Waste Stream Management

Future economic development will change the level of applicable technologies.

Stepwise Introducing of Scheme/Technology appropriate to Host Courtiers

Resource Recovery Scheme

Win-Win Situation

Disposal Mass
Disposal Hazardous Materials
Load to water and air
GHGs Emission

Appropriate Treatment Technology

Final Disposal Technology

Source Separation
Resource Recovery Plant

Base Line
Final Disposal Technology

Investment / Cost
Sustainability of System

Real and substantial merit for developing countries are;
Thank you for your attention

The 1st workshop on “Improvement of solid waste management and reduction of GHG emissions in Asia (SWGA)” on 18, January 2007 at Yokohama.

The 2nd workshop will be held at Fukuoka in next year.