TPM8 - Session 3

Presentations on Specific Research Activities at Each Institution
Disaster Waste Management after the Great East Japan Earthquake

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The Disaster: Quakes and Tsunami

Magnitude 9.0

Nationwide distribution of seismic intensity of the main quake (Meteological Agency of Japan, March 11, 2011)

Tsunami-inundated Area in Ishinomaki, Miyagi (The Geospatial Information Authority of Japan, April 18, 2011)

Flooded Area
Iwate 58 km²
Miyagi Pref. 327 km² (Ishinomaki 73 km²)
Fukushima 112 km²
Total 561 km²
Disaster Waste Categories

- Wastes generated by the quakes ("quake wastes")
- Wastes generated by the tsunami ("tsunami wastes")
- Tsunami deposits (mud, sand, sludge, sediment)
- Evacuation waste
- Fish waste
- Wastes contaminated with radionuclides (i.e., $^{137}\text{Cs}$)

Topics in this talk

- Quality and quantity of the disaster wastes
- Current situation and future on the countermeasures
- Our (NIES) activities in the field of waste management
View from Hiyoriyama Park, Ishinomaki, Miyagi (June 7, 2011)
Minami sanriku, Miyagi 
(April 16, 2011)
Survey of radioactivity in the debris in Fukushima City (June 8, 2011)
Disaster Wastes

- Tatami and mattress
- Dangerous wastes
- Vehicles and ships
- Fish wastes
"Valuables"

Photographed at Wakabayashi Gymnasium in Sendai on April 4, 2011
Estimation of waste amount

**Identifi-**
Satellite Photos
Aerial Photos
Field investigations

**Quantifi-**
Number of houses, buildings, households, enterprises

**Unit weight**
- Completely destroyed: 113 tonnes/building
- 61.2 tonnes/HH
- Half-destroyed: 0.5 of the aboves
- Flooded above floor level: 4.6 tonnes/HH
- Below floor level: 0.62 tonnes/HH

**Total weight estimation**
- Fukushima: 2.3 million tonnes
- Iwate: 4.4 million tonnes
- Miyagi: 16 million tonnes

**Total weight**


Estimated weight of the wastes (Japanese MOE)
Flow of separation and treatment of disaster waste

## Time-course scheme for waste management

<table>
<thead>
<tr>
<th>Phases</th>
<th>Actions</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Phase</td>
<td>Required to save lives, alleviate suffering and facilitate rescue operations</td>
<td>10^2 hr (3 days = 72 hr)</td>
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<tr>
<td></td>
<td></td>
<td>Initial actions (identify waste issues), Characterize, map, and assess wastes Prioritize actions</td>
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<tr>
<td>Early Recovery (relief)</td>
<td>Early Recovery (relief) Phase</td>
<td>10^3 hr (&gt; 1 month)</td>
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<tr>
<td></td>
<td>Recovery of lifelines</td>
<td>Groundwork for a disaster waste management programme to be implemented during the recovery phase Transfer of wastes to the temporary site</td>
</tr>
<tr>
<td>Recovery Phase</td>
<td>Recovery of social stocks (infrastructures)</td>
<td>10^4 hr (1 year)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Full-scale treatment or recycle of wastes</td>
</tr>
<tr>
<td>Reconstruction Phase</td>
<td>Recovery of industries</td>
<td>10^5 hr (10 years)</td>
</tr>
</tbody>
</table>

First waste storage site in Miyagino-district, Sendai (April 6, 2011)
“Minced” wastes
(Temporary storage site in Noda, Iwate
Photographed on May 6, 2011)

Hard to separate
Salt
Sediment (sludge)
Rotten, Odor
Risk of a fire
Dangerous objects

Mixed situations in which the contents are unidentified are to be avoided from the viewpoint of resource recovery, pollution control and accident prevention.
## Segregation of disaster waste, and recycling & treatment methods

<table>
<thead>
<tr>
<th>Category</th>
<th>Outline</th>
<th>Type of Waste</th>
<th>Recycling &amp; Disposal Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste from household goods</td>
<td>Household goods destroyed by earthquake and tsunami</td>
<td>Valuables and mementoes</td>
<td>Each item stored for return to owner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Home appliances (TVs, refrigerators, air conditioners, washing machines)</td>
<td>Home appliance recycling system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other home appliances</td>
<td>Metal recycled after dismantling and crushing; organic material incinerated, inorganic material disposed of in landfill</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tatami mats, mattresses</td>
<td>Shredded and used as fuel or incinerated</td>
</tr>
<tr>
<td>Waste from collapsed houses</td>
<td>Collapsed houses &amp; buildings (including furniture) destroyed by earthquake and tsunami</td>
<td>Timber from houses, furniture</td>
<td>Desalted if necessary. Potential usages include: 1) particle board, charcoal, and reuse of material; 2) use as fuel in cement kilns; 3) energy recovery from incineration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concrete, asphalt, waste tiles</td>
<td>Crushed and used as aggregate for roadbed material and in construction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asbestos-containing building materials</td>
<td>Controlled management: disposed of in landfill, melted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plasterboard</td>
<td>Controlled management: disposed of in landfill</td>
</tr>
<tr>
<td>Wood</td>
<td>Scattered and accumulated garden trees, pine wood, and other trees</td>
<td>Garden trees, live trees, etc.</td>
<td>Desalted if necessary. Potential usages after chipping include: 1) particle board, charcoal, and reuse of material, papermaking material; 2) use as fuel in cement kilns; 3) energy recovery from incineration</td>
</tr>
<tr>
<td>Bulky waste</td>
<td>Large-sized and unusual waste from factories and infrastructure</td>
<td>Tanks, power poles, feedstuffs, fertilizer, and fishing nets that each require a specific disposal method</td>
<td>Crushed and separated and then recycled, incinerated, or disposed of in landfill. Caution is required for hazardous substances such as asbestos</td>
</tr>
<tr>
<td>Deposits generated by the tsunami</td>
<td>Gravel and mud left in disaster area after the tsunami. Most is bottom sediment from water bodies, but sometimes organic materials and contaminants are included.</td>
<td>Sediments mixed by the tsunami with the debris of collapsed houses and other debris. Some include oil. Odor and dust could arise on putrefaction or drying. Hazardous chemicals such as acids, alkalis, and pesticides from the disaster area could be included.</td>
<td>Used as fill for landfills or embankments after removing woody debris and detoxifying. Detoxified by washing or incineration when material contains hazardous substances. Non-recyclable items are taken to final disposal site and disposed of as general waste. Where there is no wood debris and no contamination with a hazardous substance, they could be left in place after making arrangements with landowners.</td>
</tr>
<tr>
<td>Vehicles/ships</td>
<td>Automobiles/ships</td>
<td>Automobiles, motorbikes, tires, ships, etc.</td>
<td>Automobile recycling system. Tires chipped and used as a supplemental fuel. Ships are dismantled, recycled, and disposed of. Caution required for asbestos materials</td>
</tr>
<tr>
<td>Hazardous waste</td>
<td>Asbestos, PCBs, etc.</td>
<td>Batteries, fluorescent lamps, fire extinguishers, gas cylinders, waste oil, waste liquids, transformer oil, etc.</td>
<td>Controlled management undertaken as necessary for each type of waste</td>
</tr>
</tbody>
</table>

Sakai et al., ISWA 2011 World Congress
Example layout of the primary waste storage site

- Gamo site in Sendai
- Wood waste
- Wood waste
- Wood waste
- Vehicles
- Vehicles
- Waste oil
- Wood waste
- E-waste
- Rubbles
- Combustibles
Our (NIES) activities in the field of waste management
Management of Tsunami Sediment

Deposit pile at a temporary stock site

School playground in Sendai

Sediment: deposited mixed with wastes

- Physical and chemical property
- Possibility of chemical contamination
- Health risks (respiratory)
- Necessity for estimation of amount
- Perspectives for reuse and disposal

Sandy in the surface and muddy in the depth
Survey of sediments
(zoning and analytical approaches)

Example of zoning in Sendai

Sampling points in Sendai

Information collection of land utilization and facilities

Chemical analysis of sediments

Integrated approach to characterize the vast amount of sediment
Step toward appropriate utilization or treatment

Items
- Heavy metals
- POPs (Dioxins, PCBs, pesticides)
- Oil, Cl, etc.
Summary of chemical analysis results for sediment

The gist of the chemical analysis results (for >100 sediment samples taken at Tohoku area) is as follows. Hexane extracts exceeded 0.1% in a number of samples, and on the high end there was oily mud which was 9.8%.

While heavy metals were not detected much, lead was detected in many samples in the mg/kg range. Leaching amounts of heavy metals (using a method based on Environment Ministry Notification No. 46) were found in some instances to exceed environmental quality standards for soil contamination for lead, arsenic, fluorine, and boron. In the case of lead and arsenic, it is conceivable that natural sources were responsible for exceeding leaching standards.

There were no samples in which the content of POPs such as dioxins, PCBs, or pesticides exceeded the standards (for example, for PCBs the standard is the destruction target of 0.5 ppm for PCB treatment; for dioxins it is the environmental quality standard for soil and for sediment in bodies of water; and for other substances it is the established reference guidelines). The levels found were generally the same as the results of environmental monitoring surveys (sediment and soil) performed in recent years by the Environment Ministry in nearby water and land areas.

To date, it is safe to say that at this point no serious contamination in particular has been found.
Locations of “source” facilities and sediment sampling points in Sendai
Basic flowchart of assessment and treatment of sediment

1. **Location identification**
   - Temporary storage site
   - Source identified and heavily damaged

2. **Source identification**
   - No sources
   - Source identified
     - Problem identified
       - w/o problem
       - Category I
         - No intermediate processing
         - Usable as construction materials
         - Possible for landfilling
       - Containing wreckage but separable
       - Category II
         - Separation of wreckage
         - Usable as construction materials
         - Possible for landfilling
       - Satisfy (landfilling) standards
       - Category III
         - Separation of wreckage
         - Purification and detoxification
         - Thermal treatment
         - Possible for landfilling after intermediate processing
   - Problem identified
     - w/o problem

Ministry of the Environment (July 13, 2011):
Guidelines for treatment of tsunami deposits from the Great East Japan Earthquake,
Investigation related to health issues

• Horizontal cooperation in NIES
• Measurement of airborne particles in three towns
• Physical and chemical surveys over time in various media (i.e., atmosphere, particles, sediment and indoor dust)

Refuge in Minami-sanriku, Miyagi

Indoor dust sampled in a refuge

Hi-volume air sampler
Incineration experiments of disaster wastes (wood) in NIES

**Focusing points**
- To verify the emission increase of HCl gas and dioxins
- To check the treatability by an incineration plant well-equipped with technical countermeasures for dioxin control
- Four experiments varying input wastes (i.e., wood wastes, + salt (5%), + sediment (2%), mixtures)
- Linkage to actually operated incineration plant treating disaster wastes

Wood waste sampled in the seashore of Sendai

Wood pellets

Harbor waste (taken at Otsuchi, Iwate)
Chloride concentrations in wood wastes

Samples containing more than 0.1wt% of Cl

<table>
<thead>
<tr>
<th>Sample</th>
<th>Breadth, Thickness or Diameter / mm</th>
<th>Surface area/Volume (A/V) / cm⁻¹</th>
<th>Density/g/cm³</th>
<th>Cl / %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square timber1</td>
<td>18 □ 22</td>
<td>2.1</td>
<td>0.33</td>
<td>0.144</td>
</tr>
<tr>
<td>Square timber3</td>
<td>32 □ 90</td>
<td>0.85</td>
<td>0.41</td>
<td>0.107</td>
</tr>
<tr>
<td>Branch 1</td>
<td>D : 33</td>
<td>1.3</td>
<td>0.71</td>
<td>0.104</td>
</tr>
<tr>
<td>Tree 2</td>
<td>D : 100</td>
<td>0.40</td>
<td>0.82</td>
<td>0.262</td>
</tr>
<tr>
<td>Branch 2</td>
<td>D : 35</td>
<td>1.2</td>
<td><strong>0.30</strong></td>
<td><strong>3.35</strong></td>
</tr>
<tr>
<td>Tree 1</td>
<td>D : 75</td>
<td>0.53</td>
<td>0.47</td>
<td>0.247</td>
</tr>
<tr>
<td>Plywood1</td>
<td>2</td>
<td>10</td>
<td>0.67</td>
<td><strong>2.96</strong></td>
</tr>
<tr>
<td>Plywood2</td>
<td>5</td>
<td>4.2</td>
<td>0.63</td>
<td><strong>0.160</strong></td>
</tr>
<tr>
<td>Plywood3</td>
<td>10</td>
<td>2.3</td>
<td>0.52</td>
<td><strong>0.117</strong></td>
</tr>
<tr>
<td>Plywood4</td>
<td>10</td>
<td>2.4</td>
<td>0.52</td>
<td><strong>0.400</strong></td>
</tr>
<tr>
<td>Plywood5</td>
<td>10</td>
<td>2.3</td>
<td>0.60</td>
<td><strong>0.141</strong></td>
</tr>
<tr>
<td>Pillar5</td>
<td>100 □ 100</td>
<td>0.40</td>
<td>0.47</td>
<td><strong>0.106</strong></td>
</tr>
<tr>
<td>Pillar2</td>
<td>20</td>
<td>1.4</td>
<td>0.46</td>
<td><strong>0.461</strong></td>
</tr>
<tr>
<td>Decayed wood</td>
<td>30 □ 140</td>
<td>0.50</td>
<td><strong>0.37</strong></td>
<td><strong>0.153</strong></td>
</tr>
</tbody>
</table>
Incineration experiments at NIES pilot plant (May to August, 2011)

Gas treatment processes

Input pit and primary furnace

Sampling apparatus for dioxins
Experimental results for “salty wood waste” incineration

Change of HCl concentrations during emission gas treatment processes

Change of dioxins (TEQ) concentrations during emission gas treatment processes

Content of dioxins (TEQ) and Chlorine in the solid samples (input wastes, bottom ash and fly ash))

<table>
<thead>
<tr>
<th>PCDD/DFs</th>
<th>Wood</th>
<th>RDF</th>
<th>Bottom ash</th>
<th>Fly ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>DXN conc. (ng-TEQ/g)</td>
<td>0.0028</td>
<td>0.0033</td>
<td>0.081</td>
<td>0.3</td>
</tr>
<tr>
<td>Cl conc. (wt%[dry])</td>
<td>0.37</td>
<td>0.74</td>
<td>0.24</td>
<td>0.68</td>
</tr>
</tbody>
</table>
Issues on “radioactively contaminated waste”

1. Waste management in Fukushima Prefecture

2. Waste Management of sludge from water supply and sewage treatment in East Japan.

3. MSW and industrial waste management in East Japan

4. Others
Clearance level and exposure dose (mSv/yr)

5: Accumulated level during decontamination of dead bodies in the contaminated area

1.4: Actual level for workers at nuclear plants (average)

0.24: Actual level for workers dealing with RI (e.g., hospitals, industries, research use)

Clearance level 0.01

50: Limit for workers dealing with RI

5: 遺体の除染作業の累積値（1体/30分、1000体）

2.4: Background yearly dose (average, worldwide)

1.4: 自然界の放射線レベル (世界平均)

1: Exposure limit for general public

0.24: 放射線業務従事者の実効線量 (原子力発電所等従事の平均)

0.1: 一般公衆の線量限度 (医療は除く)

0.01: 個人が行動を決定する際に考慮に入れないリスクレベル (10⁻⁶) に相当する線量

Dose equivalent to risk level 10⁻⁶ (unaccountable level)
Relationship between spatial dose and soil level (Cs-134+Cs-137)

$R^2 = 0.642 \ (n = 568)$
Behavior of Cs during MSW incineration and melting processes
(Case study in some city in Chiba)

Input wastes: ca 40,000 tonnes

Bottom ash: 2,061 tonnes, 5,180 Bq/kg

Fly ash: 597 tonnes, 57,600 Bq/kg

Fly ash (melting process): 430 tonnes, 70,800 Bq/kg

Molten slag: 2,368 tonnes, 459 Bq/kg
Leaching characteristics of Cs

Soil (土壌)
- 有機 20%
- 粘土鉱物との強固な結合態 70%
- 放射性セシウム 10%

Bottom ash (焼却主灰)
- 主灰 98%
- 水 2%

Fly ash (焼却飛灰)
- 水 67%
- 飛灰 33%

Molten slag (溶融スラグ)
- 水 12%
- スラグ 88%

Fly ash obtained during melting process
- 水 100%


**Leaching test (a method based on Environment Ministry Notification No. 46)
S/L ratio = 50g/500mL, shaking for 6 hours followed by 0.45 μm membrane filtering
Current Guideline for the Cs-contaminated wastes

• < 8,000 Bq/kg: landfilling possible (soil or bentonite underneath, immediate soil covering)

• > 8,000 Bq/kg, < 100,000 Bq/kg: temporary storage at controlled landfill sites with special cares (i.e., requirements for structural conditions at the sites, vessels, and distance limit from the boundary)

• >100,000 Bq/kg: stringent storage and management

Special Law will be fully enforced from the beginning of next year. Detailed technical and administrative guidelines will be soon proposed by the Government.
Conclusive Remarks

1. Aiming at rapid, safe and economical waste management
   - Priority on public QOL
   - Partnership (“all-Japan” approach and local recovery)
   - Leadership

2. Focus on resource and hazard aspects of disaster wastes
   - Characterization of wastes followed by appropriate separation
   - Primarily prioritize on reuse and recycle
   - Prevention of secondary environmental pollution
   - Long-lasting efforts toward radionuclide waste management
   - Risk communication

3. Record and report