Damage to Sewage Treatment Systems caused by the Great East Japan Earthquake and the Government’s Response

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Great East Japan Earthquake (also known as “2011 Tohoku earthquake”)
Occurred at 2:46 PM on Friday, March 11, 2011
Measured 9.0 (M$_w$) on the Richter scale

Seismic Intensity

- Strong
- Weak

- 7 7
- 6+ 6 upper
- 6 6 lower
- 5+ 5 upper
- 5- 5 lower
- 4 4
- 3 3
- 2 2
- 1 1

Aftershocks so far
- 698 times, M5.0~
- 105 times, M6.0~
- 6 times, M7.0~
Tsunami caused by the earthquake was the most devastating ever

9.3 m high at Soma City.
Run-up heights of over 40 m in some area
Inundation area was 561 km$^2$
(a linear distance of 650 km)
Community residence as well as local government suffered serious damage.
Information was inconsistent and fragmental. Many local gov’t were unable to determine the extent of the damage.

Mar. 15
Ministry of Land Infrastructure Transport, Tourism (MLIT) set up “The Sewage Response Headquarters” in Miyagi and Tokyo.

Its main purpose is to manage disaster support & handle the information for assistance.
More than 6,000 staff from various local government assisted those damaged local government.
Basic Concept of Supporting system

In the disaster area

On-site Sewage Response Headquarter
(in Miyagi, MLIT)

Support request

Stricken government

In other areas

Support activities

Support Local governments

Sewage Support Headquarter
(in Tokyo, MLIT)

Correspond

Correspond

5/21
Almost all buildings were destroyed by tsunami in Miyagi
A 3-stories building was unable to withstand the tsunami.
Damage by wave force of the tsunami
Damage to WWTP – Column

The column of wall distorted by the tsunami
Electric equipment room flooded by tsunami
Damage to WWTP – Mechanical Equipment

Basement machine rooms flooded in many WWTPs
Damaged by Floating Debris

Car wreckage are in aeration tank
### Damage situation of WWTPs

<table>
<thead>
<tr>
<th>Working situation of WWTPs</th>
<th>March 16, 2011</th>
<th>May 10, 2012</th>
<th>March 5, 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation shut down*</td>
<td>44</td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>Partly damaged</td>
<td>67</td>
<td>44</td>
<td>12</td>
</tr>
<tr>
<td>Unclear (Nuclear Power Plant area)</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Full restoration</td>
<td>---</td>
<td>48</td>
<td>97</td>
</tr>
<tr>
<td>Total</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
</tbody>
</table>

“Study committee for earthquake and tsunami countermeasure techniques in sewage systems” had much to contribute to restoration.

Objective: To indicate a road map for early restoration
Member: Experts, Local government, and MLIT*, etc.

The damaged wastewater treatment plants in east Japan
# Government’s Response

- **Mar. 11** Earthquake occurrence
- **Mar. 15** “The Sewage Response Headquarters” was set up in Tohoku

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr. 12 2011</td>
<td>Establishment of the Study committee</td>
</tr>
<tr>
<td>Apr. 12 2011</td>
<td>(1&lt;sup&gt;st&lt;/sup&gt; proposal) The proposals for emergency technical info</td>
</tr>
<tr>
<td>Jun. 14 2011</td>
<td>(2&lt;sup&gt;nd&lt;/sup&gt; proposal) Phased emergency restoration methods</td>
</tr>
<tr>
<td>Aug. 15 2011</td>
<td>(3&lt;sup&gt;rd&lt;/sup&gt; proposal) Final restoration methods</td>
</tr>
<tr>
<td>Mar. 8 2012</td>
<td>(4&lt;sup&gt;th&lt;/sup&gt; proposal) Protection measures against tsunami</td>
</tr>
</tbody>
</table>
Damaged sewage systems need the earliest possible restoration. However, considering the scale of the disaster, a substantial amount of time will be required before restoration can be completed.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Action</td>
<td>Action immediately after disaster. Sterilization is necessary.</td>
</tr>
<tr>
<td>Emergency Restoration</td>
<td>Temporary restoration when Final Restoration takes long time</td>
</tr>
<tr>
<td></td>
<td>Improvement in sanitation and Countermeasure for inundation.</td>
</tr>
<tr>
<td>(1) The case estimated 3-6 months till final restoration</td>
<td>(2) <strong>Within 1 year</strong></td>
</tr>
<tr>
<td></td>
<td>- Sedimentation</td>
</tr>
<tr>
<td></td>
<td>- Simple Biotreatment</td>
</tr>
<tr>
<td></td>
<td>- Sterilization</td>
</tr>
<tr>
<td>(2) Within 1 year</td>
<td>(3) 1-3 years</td>
</tr>
<tr>
<td></td>
<td>- Biotreatment</td>
</tr>
<tr>
<td></td>
<td>- Sedimentation</td>
</tr>
<tr>
<td></td>
<td>- Sterilization</td>
</tr>
<tr>
<td>(3) 1-3 years</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Target BOD</td>
<td>120 mg/L</td>
</tr>
<tr>
<td></td>
<td>120-60</td>
</tr>
<tr>
<td></td>
<td>60-15</td>
</tr>
<tr>
<td>Final Restoration</td>
<td>Full functional restoration plus disaster prevention.</td>
</tr>
<tr>
<td>Target BOD</td>
<td>Less than 15 mg/L</td>
</tr>
<tr>
<td>Coliform</td>
<td>Less than 3,000 cells/cm³ in any phases</td>
</tr>
</tbody>
</table>
Emergency Restoration – Simple biotreatment

Simple discharge

Contact oxidation methods

Sterilization by Calcium hypochlorite
Emergency Restoration – Biotreatment

Simple discharge → Activation sludge treatment

blower
In sewage system, there was no policy against tsunami

Sewage system had no safety regulations in regard to tsunami occurrence

Damage by tsunami is categorized into 3 groups

- Wave Force
- Inundation
- Debris

The study committee proposed a required capability and countermeasures for sewage system on a tsunami hit, suppose worst-case scenario
### The View of the Sewage Treatment Plants Design in Consideration of Tsunami Protection Measures

#### The function, should be maintained on tsunami occurrence in each sewage facility

<table>
<thead>
<tr>
<th>Type of facility</th>
<th>Sewer system</th>
<th>Pump station</th>
<th>Treatment plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional category</td>
<td>Essential functions</td>
<td>Other functions</td>
<td></td>
</tr>
<tr>
<td>Backflow prevention</td>
<td>Pumping</td>
<td>Pumping Sterilization</td>
<td>Sedimentation Dewatering</td>
</tr>
<tr>
<td>Tsunami resistance</td>
<td>“Must be maintained” even in a disaster situation</td>
<td>Although Functional Suspension is Accepted temporary “should be restored quickly”</td>
<td>Although temporary suspension is acceptable, it “should be restored on early stage”</td>
</tr>
<tr>
<td>Type of protection</td>
<td>Risk avoidance</td>
<td>Risk reduction</td>
<td>Risk retention</td>
</tr>
</tbody>
</table>
Example of Tsunami-Resistant Countermeasures

**Risk avoidance**
- Reinforcing of building
  - Structure: -
  - Opening: -
  - M/E: -
  - Others: Protection wall

**Risk reduction**
- Reinforce a part of WWTP
  - Structure: tsunami-resistant wall
  - Opening: -
  - M/E: high place

**Risk retention**
- Allow equipment to be destroyed
  - Structure: -
  - Opening: -
  - M/E: high place
  - Others: non-structural measures

Tsunami height:
- Opening (without action)
- M/E equipment (without action)
- Opening (waterproofing)
- M/E equipment (waterproofing)
- Indoor inundation
Damage to sewage treatment systems caused by the great east Japan earthquake and the government’s response

- The degree of damage in wastewater treatment plants by tsunami was the largest in history in Japan
- MLIT constructed the supporting system and set up sewage support headquarters, and established the study committee
- The study committee proposed phased emergency restoration methods and a new tsunami-resident policy
- In the future, this policy needs to be more widespread
Thank you for your Attention!
Damage to sewage systems
Characteristics of Damage to Sewerage

Tohoku Region
- WWTPs flooded by tsunami
- Sewers broken by land subsidence

Kanto Region
- Sewers broken by soil liquefaction

600 km
370 mile
JMA Seismic Intensity Scale
(Japan Meteorological Agency)

1: Felt by only some people indoors.

6-: Difficult to keep standing.

6+: Impossible to keep standing and to move without crawling.

7: Thrown by the shaking and impossible to move at will.

<table>
<thead>
<tr>
<th>USA</th>
<th>I</th>
<th>II-III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japanese</td>
<td>0~1</td>
<td>1~3</td>
<td>3</td>
<td>4</td>
<td>5 lower</td>
<td>5 upper</td>
<td>6 lower</td>
<td>6 upper ~7</td>
<td>7</td>
</tr>
</tbody>
</table>
Example for Emergency Measures

Kennan WWTP in Miyagi Pref.

- Temporary pumps were installed
- Temporary ponds for sedimentation treatment
Up-floated Sewer & Manhole

Sand clogged manhole
The ratio of disaster

Earthquake
- Civil engineering structure: 31.4%
- Building structure: 15.7%
- Mechanical equipment: 38.1%
- Electric equipment: 14.8%

Tsunami
- Civil engineering structure: 19.9%
- Building structure: 20.2%
- Mechanical equipment: 29.6%
- Electric equipment: 30.3%