The 2011 Tohoku earthquake, tsunami, and Fukushima nuclear accident: the Risk Policy Aftermath

Atsuo KISHIMOTO
Research Institute of Science for Safety and Sustainability (RISS)
In National Institute of Advanced Industrial Science and Technology (AIST)
Tsukuba, Japan
E-mail: kishimoto-atsuo@aist.go.jp
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The multiple risk situations

**Earthquake**
- March 11, 2011, at 14:46
- Magnitude: 9.0
- 15,883 dead
- 2,654 missing

**Tsunami**
- Evacuation
- Supply-chain disruption

**Nuclear accident**
- Radionuclides fallout
- Potential health effects*
  - Stress (mental and physical)
  - * unproven.

**Energy shortage**
- Energy price hike

**Radionuclides fallout**
- Result of aircraft monitoring by MEXT and U.S.DOE (as of April 2011)

The number of evacuees is about 290,000 as of August 12, 2013.

* unproven.
Personal experience in March 2011

- Strong and long-continued quakes
- Three days without tap water
- Real-time risk management
- Preparing to evacuate to Kobe

Tsukuba 170km
Tokyo 230km

Fukushima Daiichi nuclear power plant

Earthquake Epicenter

Air dose rate in Tsukuba

Hydrogen explosions (12-15 March)

Rainfall (21 March)
Shift in the share of electric power suppliers' power sources

Electricity prices were raised by 30% on average.

http://www.enecho.meti.go.jp/info/committee/sougoubukai/1st/1stsankou1-1.pdf
Restart applications (July 2013)

The Risk Policy before 3.11

Earthquake

Tsunami

Nuclear power plants
A deep conflict between proponents and opponents of nuclear energy has blocked risk discussions and reasonable preparations.

→ *Preparation for emergency* was difficult for the proponents, because their premises contradicted each other.
→ Implementation of *probabilistic risk assessment (PRA)* and discussion on handling of *residual risks* has not progressed.

**Lack of risk based approach: Nuclear power**

Nuclear power cannot be accepted unless the probability of severe accidents is **zero**.

→ Severe accidents will **never** happen at the nuclear power plants in Japan.

**Opponents**

- Nuclear power cannot be accepted unless the probability of severe accidents is **zero**.

→ Preparation for emergency was difficult for the proponents, because their premises contradicted each other.
→ Implementation of probabilistic risk assessment (PRA) and discussion on handling of residual risks has not progressed.

**Litigation arguments**

→ A strange balance was achieved.

**METI** (Ministry of Economy, Trade and Industry)

**Regulatory capture**

**Electric companies**
Limitation of risk based approach: Earthquake

National seismic risk map

Probability distribution of seismic intensity 6 within 30 years.


Hanshin-Awaji earthquake in Jan. 1995 counted 6,437 deaths.

Tohoku earthquake in March 2011 counted 18,537 deaths.

National active fault map

Active faults *other than* these major 110 ones triggered all 14 earthquakes occurred after the 1995 Hanshin-Awaji (Kobe) earthquake.

http://www.asahi.com/special/bousai/TKY201208310466.html

But, recent big earthquakes have occurred in places of “low probability” or beyond expectations.

Much emphasis has been placed on Tokai area on the assumption of *predictability*!

The government selected 110 active faults as major ones among more than 2,000.

(The Headquarters for Earthquake Research Promotion)
The Risk Policy Aftermath

Earthquake

1995 Hanshin-Awaji (Kobe) earthquake

Tsunami

Nuclear power plants
Active fault issue: A key to restart NPPs
The proof of active faults can shut down NPPs

New safety standards (enacted in July, 2013)
- Power sources, cooling facilities
- Measures against severe accidents
  Quake-proof emergency response center
  Filtered venting equipment
- Measures against tsunami, earthquakes, fires, volcanic eruptions, tornadoes, terrorist attacks

“Facilities with important safety functions shall be established where no appearance of a fault with the possibility of becoming active in the future is confirmed.”
(Basic Design Policy for Earthquakes and Tsunamis)

“It is difficult to estimate shift length, deformation volume, and the force to lift up facilities.” (NRA 2013)
Active faults are generally defined as *faults that have traces of repeated past movements and may trigger earthquakes in the future*. In reality, to judge whether a fault is active or not is very difficult.

<table>
<thead>
<tr>
<th>Academic vs. regulatory definition of <strong>active faults</strong></th>
<th>Institutions</th>
<th>Time limit for reviewing</th>
<th>Period to be examined</th>
<th>Default assumption when active faults are found</th>
<th>Consequences when active faults are found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old guideline (1978)</td>
<td>Atomic Energy Commission (AEC)</td>
<td>Not mentioned</td>
<td>Past 50,000 years</td>
<td>No active fault if no evidence of movement is found.</td>
<td>Not mentioned</td>
</tr>
<tr>
<td>Revised guideline (2006)</td>
<td>Nuclear Safety Commission (NSC)</td>
<td>Not mentioned</td>
<td>Past 120,000 to 130,000 years</td>
<td>Active fault if evidence of no movement is found. (not fully implemented, in reality)</td>
<td>Not mentioned</td>
</tr>
<tr>
<td>New safety standards (2013)</td>
<td>Nuclear regulatory Authority (NRA)</td>
<td>Before restarting reactors</td>
<td>Past 400,000 years (in case of insufficient data).</td>
<td>Active fault if evidence of no movement is found. (strictly implemented)</td>
<td>Reactors will be prohibited to operate.</td>
</tr>
</tbody>
</table>
Expert panels on the investigation of onsite faults: a case of Ohi NPP

Prof. Watanabe (Toyo Univ.)
(Tectonic Geomorphology)

This must be an active fault.

(Prof. Watanabe’s) interpretation is consistent with the facts.

Prof. Hirouchi (Shinshu Univ.)
(Tectonic Geomorphology)

Commissioner Shimazaki
(Seismology)

This is a landslide, not an active fault.

Dr. Shigematsu (AIST)
(Tectonic Geology)

This is probably not an active fault.

Neutral

The time when the fault moved in the past dates back more than 400,000 years, according to the analysis of minerals in the fault.

Prof. Okada (Kyoto Univ.)
(Tectonic Geomorphology)

Ohi

Thoughts:
- This must be an active fault.
- (Prof. Watanabe’s) interpretation is consistent with the facts.
- This is a landslide, not an active fault.
- This is probably not an active fault.
- The time when the fault moved in the past dates back more than 400,000 years, according to the analysis of minerals in the fault.
Volcanic eruption issue: Is this risk played down?
Preparing for volcanic eruptions

Mega-earthquakes since 20th century accompanied volcanic eruptions in the following years.

The new safety standard contains a guidance on assessing the impact of volcanic eruptions on NPPs. "Active volcanos" within 160 km?

Is a probability of being affected by pyroclastic flows* sufficiently small during operation?

*destructive streams of heated rocks and gasses.

Impact assessment & Management

YES

Disapproval

NO
**Regulatory** definition of “Active volcanos”

Transition of the definition of “active”

1975: a volcano that has had records of at least one eruption (77)

1991: a volcano that has had at least one eruption during the past 2,000 years (86)

2003: a volcano that has had at least one eruption during the past 10,000 years (110)
History of *super-colossal* eruptions

12 super-colossal eruptions occurred in the past 120,000 years. (Volume of volcanic product is more than 100km$^3$: VEI 7)

- **Aso caldera**: 900,000 yrs ago
- **Ata caldera**: 85,000 yrs ago
- **Kikai caldera**: 7,300 yrs ago
- **Aira caldera**: 29,000 yrs ago
- **Kussharo caldera**: 110,000 yrs ago
- **Tota caldera**: 110,000 yrs ago
- **Towada caldera**: 10,000 yrs ago
- **Shikotsu caldera**: 32,000 yrs ago
- **Akan caldera**: 110,000 yrs ago
- **Hakone caldera**: 60,000 yrs ago
- **Tomari NPP**: 32,000 yrs ago
- **Ikata NPP**: 10,000 yrs ago
- **Genkai NPP**: 900,000 yrs ago
- **Sendai NPP**: 29,000 yrs ago

*Note: The image includes a map with locations marked by calderas and nuclear power plants.*
90,000 years ago (600km³): A volcanic eruption destroyed prehistoric culture. It took 900 years for evergreen forests to return to the area.

29,000 years ago (450km³): Calderas in Kyushu area

7,300 years ago (170km³): A volcanic eruption destroyed prehistoric culture. It took 900 years for evergreen forests to return to the area.

http://kazan-net.jp/shitoWWW/pfrotou.html
Seawall issue:
Do we need a larger one?
A case of *Taro* in *Miyako* city, *Iwate* prefecture

**1896**  Meiji Sanriku Tsunami (15 meter): All houses were swept up (100%) and 1,867 died (83%)
⇒ Collective relocation was considered but, given up

**1933**  Showa Sanriku tsunami: 500 houses were swept up (83%) and 911 died (32%)
⇒ A seawall was planned because moving to uplands was not compatible with living by fishing.

**1934**  Started to construct a seawall

[Image: http://www.mlit.go.jp/river/kaigan/main/kaigandukuri/tsunamibousai/03/index3_2.htm]
[Image: http://upload.wikimedia.org/wikipedia/commons/2/27/Sanriku_Great_Tsunami.JPG]
1957 10-meter high, 25-meter wide, 1,350-meter long seawall was completed.

1960 Chile Tsunami (3-6 meter): Damages being so small, the seawall got attention from tsunami researchers around the world.

1978 Second seawall with 1083 meter length was completed.

2003 Declaration of “Tsunami proof town”

2011 Tsunami (15 meter) completely destroyed and 229 died (5%)
The Great Seawall Plan

15 meter high seawalls (5-storey building) are being built along the Tohoku Pacific Coast.

<table>
<thead>
<tr>
<th>Cases</th>
<th>Extensions (km)</th>
<th>Project cost (billion $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iwate</td>
<td>135</td>
<td>66.6</td>
</tr>
<tr>
<td>Miyagi</td>
<td>392</td>
<td>248.1</td>
</tr>
<tr>
<td>Fukushima</td>
<td>78</td>
<td>74.6</td>
</tr>
<tr>
<td>Sum</td>
<td>605</td>
<td>389.3</td>
</tr>
</tbody>
</table>

(Kahoku Shimpo Publishing Co.)

http://www.kahoku.co.jp/spe/spe_sys1071/20130906_01.htm
Problems with great seawalls

Economic
- A high maintenance cost.

Ecological
- Damage to coastal ecology

Safety
- Not sufficient for the 2011 tsunami
- A possible delay in evacuation

Procedural
- Without public consultation
- No options presented
- No cost effectiveness estimation
- No environmental assessment
Preparing for the next big tsunami

- Nankai Trough earthquakes have occurred at intervals of 90 - 150 years.
- The government assumed that the next earthquake would occur around 2030 and the death tolls could reach 320,000 in the worst case scenario.

Repeated Nankai Trough earthquakes:
- 1096, 1099
- 1361
- 1498
- 1605
- 1707
- 1854
- 1944, 1946
- 2030?

Will all Japanese coastlines be surrounded by great seawalls?
Decontamination issue:
Is it possible to restore the land?

30cm topsoil plowing

Shot-blasting

Temporarily stored bags of decontamination wastes

Removal of weeds and plants in gardens

http://www.jaea.go.jp/fukushima/decon04/ke02.pdf

Lack of cost-effectiveness assessment

The government makes it a principle to achieve “less than 1mSv/year” for each person.

No one had evaluated the feasibility, effectiveness, time, practical goals and costs of decontamination activities.
Estimation of costs and effectiveness

Special Decontamination Areas

**Effectiveness** (external exposure dose rate)


**Costs**

- A cheaper alternative
- Decontamination
- Temporary storage
- Container for temporary storage
- Interim storage

*Not including the costs of final disposal*
Will residents really return to their towns?

After the accident, the emergency evacuation preparation zone was designated to areas between 20km and 30km line. But, nearly 40% continues to evacuate from these areas even after evacuation instruction was lifted.

Reclassification in April 2012

- Decontamination implementation area
- Areas ready for the lifting of evacuation orders
- Residence-restricted area with visitation-only access
- Residence-prohibited area for a long period of time

Only 20% has returned

Only 17% has returned
Too much precaution

Scientists must say "We can’t draw a conclusion" when there is uncertainty.

Too little precaution

Decision-making must be conducted even when there is uncertainty!

Pure science

Policy decision-making

Risk analysis
Impact assessment

Active faults, Seawall Decontamination

Tsunami (before the accident)
Volcanic eruptions
Why is risk / impact assessment not utilized?

1. **Sub-goals** has replaced the **true goal**.
   - =means
     - Active faults beneath NPPs
     - Construction of seawalls
     - Decontamination activities
   - =ends
     - Risk reduction

2. Measures have been required not from the viewpoint of **risk**, but that of **liability and management**.

3. **Cost and effectiveness** is not paid attention because the budget comes from the central government.

4. Considering cost and risk has been **taboo**.
A monument of the Ansei Nankai Trough earthquake tsunami (1854)

“Get inked in this stone monument every year so that everyone can read characters on this monument.”

With historical perspective and risk analysis, we can live with earthquakes, tsunami and volcanos much better.

Thank you for your attention!