Program of the Analysis and Research Laboratory for Fukushima-Daiichi and Advanced Techniques to be Applied in the Laboratory

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Introduction (1)

- **Current Status of Fukushima Dai-ichi Nuclear Power Plant**

  - The nuclear fuels in Unit 1-3 are being cooled in a stable condition and radioactive material release from the reactor buildings is kept at a low level.

  - Most of high dose rubbles have remained untouched in the destroyed reactor buildings. (Unit 1-2)
  - Secondary wastes such as cesium adsorption vessels and sludge have been increasing. (Unit 1-3)
  - Fuel debris has remained untouched. (Unit 1-3)
Introduction (2)

- Mid-and-long-Term Roadmap for the decommissioning of Fukushima Dai-ichi Nuclear Power Plant (1F-NPP)

March, 2011

- Completed (on Dec 16th, 2011)
- Step 1
  - Cold shutdown condition
  - Suppression of release of radioactive materials
- Step 2

Phase 1
- Up to 2 year from Step2 completion time
- Up to the start of fuel removal in spent fuel pool

Phase 2
- Up to 10 year from Step2 completion time
- Up to the start of fuel debris removal in Unit 1-3

Phase 3
- Up to 30-40 year from Step2 completion time
- Up to completion of decommissioning of 1F-NPP

Main future work

- Fuel debris removal (Phase 2)
  - Need to determine fuel debris removal method
  - Need to removal high dose rubbles remained in the reactor buildings
    (This prevents human from access into the buildings.)

- Determination of the waste treatment and disposal method (Phase 2 - Phase 3)
  - Need to clarify the characteristics of rubbles
  - Need to clarify the characteristics of secondary wastes
  - Need to clarify the characteristics of fuel debris
Example of Radioactive Waste

- Rubbles
  A part of rubbles have been stored in the 1F site but most of them have remained untouched in the reactor buildings. Cut down trees and soil, which were removed to construct some new facilities in 1F site, were also generated. And, they have been also stored in temporary storage facilities.

- Secondary wastes
  Contaminated water generated by cooling of nuclear fuel has been clean up. The secondary wastes such as cesium absorption vessels and sludge have been also increasing.

- Debris
  Fuel debris were generated by the loss of cooling and feeding functions. There are also high dose materials such as reactor structural materials and other decommissioning waste in reactor.

### Example of Radioactive Waste

<table>
<thead>
<tr>
<th>Items</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubbles</td>
<td>Rubbles, Cut down trees soil</td>
</tr>
<tr>
<td>Secondary wastes</td>
<td>Sludge, Absorption vessel etc.</td>
</tr>
<tr>
<td>Debris</td>
<td>Fuel debris</td>
</tr>
<tr>
<td></td>
<td>- High dose materials</td>
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<tr>
<td></td>
<td>- Reactor structural materials</td>
</tr>
<tr>
<td></td>
<td>- Decommissioning waste</td>
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</table>

Radioactive wastes are classified in 3 categories.
Radioactive Waste Processing and Disposal Plan in Mid-and-long-Term Roadmap

- Basic guideline
  Depending on the characteristics of the radioactive wastes (the radionuclides and its level of radioactivity), it will be subject to processing such as being sealed in containers and encased in concrete to form blocks of waste and transported to a waste disposal site and buried.

- Research plan
  The research and development necessary for the processing and disposal of the waste will be conducted on the basis of collaboration between the national government, TEPCO, related industries and research organizations.

Role of JAEA

- The waste treatment and disposal methods for rubbles, secondary wastes and debris are not determined yet. In order to advance the decommissioning project safely and timely, it is important to determine the methods soon.
Construction Planning of Facility

**History**
- For research and development on the decommissioning of TEPCO’s Fukushima Dai-ichi Nuclear Power Plant, **85 billion yen** was financed to Japan Atomic Energy Agency to construct the research facilities as a supplementary budget in 2012 by Japanese Ministry of Economy, Trade and Industry (METI).
- In JAEA, “Nuclear Plant Decommissioning Safety Research Establishment” was established for this project on April 1, 2013. Now, it changes to “Fukushima Research Infrastructural Creation Center”.

**Construction Plan of Facility**
- As an essential research center for the decommissioning of 1F, following advanced research facilities will be constructed using 85 billion yen.
  - Remote-controlled equipment and device development facility in Naraha Remote Technology Development Center to develop the removal technique of fuel debris
  - Radioactive materials analysis and research facility in Okuma Analysis and Research Center to investigate the characteristics of radioactive waste
Facilities at Analysis and Research Center

1st. Stage Facility

- Administrative building
  - Office work, entrance control and emergency management

- Laboratory-1 (Low dose materials)
  - Analysis of radioactive wastes such as rubbles and secondary wastes for its characterization
  - Analysis for technology development of waste treatment and disposal
  - Development of analytical technology

2nd. Stage Facility

- Laboratory-2 (High dose materials including fuel debris)
  - Analysis of debris for its characterization
  - Analysis for substantial removal of fuel debris
  - Analysis for technology development of treatment and disposal of high dose wastes
  - Development of analytical technology
The operational start time of the facility is under investigation including the period of design and licensing works.

**Schedule for facility construction**
- The detail design of 1\textsuperscript{st} stage facility (Administrative building and Laboratory-1) has been already started.
- The detail design of 2\textsuperscript{nd} stage facility (Laboratory-2) will be started soon.

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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative building (office)</td>
<td>Design</td>
<td>Construction</td>
<td>Operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory-1</td>
<td>Design</td>
<td>Construction</td>
<td>Operation</td>
<td>Licensing work</td>
<td>Operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Laboratory-2</td>
<td>Design*</td>
<td>Construction*</td>
<td>Operation*</td>
<td>Licensing work*</td>
<td>Operation*</td>
<td></td>
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</table>

* The operational start time of the facility is under investigation including the period of design and licensing works.
The suitable location of both laboratories to analyse radioactive wastes is considered in terms of below requirements.

- It should be located in 1F site for easy and safe transfer of samples.
- Air dose rate in facilities has to be low enough for low exposure of employees and accurate analysis.
- Infrastructure of utility, water and so on should be ready or to be easily prepared. And there should be little issues of logistics, such as enough width of approach roads.
- Enough area, rather flat, and no big site preparation
Construction Site (2)

Currently, the site has been tentatively selected in 1F site which is located at Okuma-machi in Fukushima prefecture.
## Analysis Objects

<table>
<thead>
<tr>
<th>Objects</th>
<th>Candidate for analysis</th>
<th>Lab-1</th>
<th>Lab-2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rubble etc.</strong></td>
<td><strong>Concrete, metal</strong></td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Cut-down plants</td>
<td><strong>Cut-down plants for land preparation</strong></td>
<td>○</td>
<td>—</td>
</tr>
<tr>
<td>Soil</td>
<td><strong>Surface soil in 1F site</strong></td>
<td>○</td>
<td>—</td>
</tr>
<tr>
<td>Burned ash</td>
<td><strong>Burned ash such as cut-down plants and hazard suit</strong></td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>Secondary wastes</strong></td>
<td><strong>Decontamination equipment</strong></td>
<td></td>
<td>(○)</td>
</tr>
<tr>
<td></td>
<td>- sediment of Barium sulfate, etc</td>
<td>○</td>
<td>(○)</td>
</tr>
<tr>
<td></td>
<td><strong>Advanced Liquid Processing System</strong> (Multi nuclides removal equipment: called “ALPS”)</td>
<td>○</td>
<td>(○)</td>
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<tr>
<td></td>
<td>- Iron hydroxide sludge, etc</td>
<td></td>
<td>(○)</td>
</tr>
<tr>
<td>Sludge</td>
<td><strong>ALPS</strong></td>
<td>○</td>
<td>(○)</td>
</tr>
<tr>
<td></td>
<td>- Activated carbon, Titanate, chelating resin etc.</td>
<td>○</td>
<td>(○)</td>
</tr>
<tr>
<td>Absorption material Sludge</td>
<td><strong>Cesium absorption equipment</strong></td>
<td></td>
<td>(○)</td>
</tr>
<tr>
<td></td>
<td>- Zeolite (Kurion (USA))</td>
<td></td>
<td>(○)</td>
</tr>
<tr>
<td></td>
<td><strong>Cesium absorption equipment</strong></td>
<td></td>
<td>(○)</td>
</tr>
<tr>
<td></td>
<td>- Zeolite (SARRY)</td>
<td></td>
<td>(○)</td>
</tr>
<tr>
<td>Water from desalinization</td>
<td><strong>Water from desalinization equipment</strong></td>
<td>○</td>
<td>—</td>
</tr>
<tr>
<td>equipment</td>
<td>- Concentration salt water, Concentrated liquid waste</td>
<td>○</td>
<td>—</td>
</tr>
<tr>
<td>Fuel debris</td>
<td><strong>Oxide</strong>: (U,Zr)O$_2$-X, (U,Pu,Zr)O$_2$-X, etc</td>
<td></td>
<td>(○)</td>
</tr>
<tr>
<td></td>
<td><strong>Alloy</strong>: U-Zr-Fe, U-Pu-Zr-Fe, etc</td>
<td></td>
<td>(○)</td>
</tr>
<tr>
<td></td>
<td><strong>Molten corium</strong></td>
<td></td>
<td>(○)</td>
</tr>
<tr>
<td>Reactor core constructional material</td>
<td><strong>Reactor pressure vessel(RPV), Primary containment vessel(PCV), Constructional material in RPV</strong></td>
<td></td>
<td>(○)</td>
</tr>
<tr>
<td>Demolition waste</td>
<td><strong>Concrete, Apparatus, etc</strong></td>
<td></td>
<td>(○)</td>
</tr>
</tbody>
</table>

- ○: Treated
- (○): Having a possibility of treatment
- —: Not treated
# Acceptance guideline in Laboratory-1

## Acceptance guideline (Under consideration)

- It is assumed that most of radioactive materials to be received in Laboratory-1 are low dose ones (lower than 1 mSv/h).

- Rubbles and secondary wastes up to the surface dose rate of 1 Sv/h will be treated.

- 1600 samples of the radioactive materials such as rubbles and secondary waste will be received per year.

<table>
<thead>
<tr>
<th>Items</th>
<th>Receives /year</th>
<th>Acceptance guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubble etc.</td>
<td>1600 samples</td>
<td>【low dose materials】&lt;br&gt;• Surface dose rate: Lower than 1 mSv/h&lt;br&gt;• Weight: About 100 g/batch&lt;br&gt;• Maximum size: Need to pass a pair of swinging doors&lt;br&gt;• Maximum weight: Up to about 300 kg</td>
</tr>
<tr>
<td>Secondary wastes</td>
<td></td>
<td>【high dose materials】&lt;br&gt;• Surface dose rate: Up to about 1 Sv/h (not absolute limitation)&lt;br&gt;• Weight: About 100 g/batch&lt;br&gt;• Maximum size: Need to be handled in iron cells&lt;br&gt;• Maximum weight: Up to about 2 kg/batch</td>
</tr>
</tbody>
</table>
Acceptance guideline in Laboratory-2

- **Acceptance guideline (Under consideration)**
  - Rubbles and secondary wastes beyond the surface dose rate of 1 Sv/h will be treated in Laboratory-2.
  - The receiving amount of fuel debris is estimated to be 12 samples per year. (Not determined yet)
  - The acceptance guidelines of weight and size for fuel debris are not determined.

<table>
<thead>
<tr>
<th>Items</th>
<th>Receives /year</th>
<th>Acceptance guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubble etc.</td>
<td>150 samples (temporary estimation by JAEA)</td>
<td>• Surface dose rate in shielding container: less than 2 mSv/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Weight: About 100g/batch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Others: Not determined</td>
</tr>
<tr>
<td>Secondary wastes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel debris etc.</td>
<td>12 samples (temporary estimation by JAEA)</td>
<td>• Not determined</td>
</tr>
</tbody>
</table>
Analysis plan

- **Analysis plan in Laboratory-1 (Under consideration)**
  - Radioactivity analysis of key nuclides (38 nuclides) which can be considered for evaluation of waste disposal method (→Inventory evaluation for rubbles and secondary wastes)
  - Evaluation for chemical-bonding state of radioactive nuclides, which affects the diffusion coefficient under the soil
  - Chemical analysis of harmful materials which influence the waste configuration and environment
  - Mechanical property and physical property measurement for integrity assessment of 1F buildings and the waste configuration
  - Other analysis, for example hydrogen generation rate in long-term storage.

- **Analysis plan in Laboratory-2 (Under consideration)**
  - Chemical and physical property measurement of fuel debris for its characterization
  - Radioactivity analysis of key nuclides (38 nuclides) for high dose rubbles and secondary wastes
  - Evaluation for chemical reaction such as corrosion between fuel debris and the storage flask
  - Evaluation for generation of burnable gas which can cause fire and explosion in long-term storage
  - Analysis for estimation of the extension behavior of the 1F-NPP accident
Main material flow in Laboratory-1 (1)

- **Low dose radioactive waste**

  Surface dose rate: < 1mSv/h

- Low dose materials (<300 kg/batch) will be transferred from a storage facility in 1F site to a sealed house of Laboratory-1. Sample preparation will be roughly performed by hand work.

- In grove box, precise sample preparation will be carried out.

- In hood, precise sample preparation and chemical separation will be carried out.

- In test room, most various analyses and measurement will be done.
Main material flow in Laboratory-1 (2)

- **High dose radioactive waste**

  Surface dose rate : < 1Sv/h  
  (Not absolute limitation)

- The receive area will be an iron cell in terms of reduction of radiation exposure. Sample preparation will be roughly performed.

- In grove box, precise sample preparation will be mainly carried out.

- In hood, precise sample preparation and chemical separation will be mainly carried out.

- In test room, most various analyses and measurement will be done.
*High dose materials including fuel debris*

Surface dose rate: > 1Sv/h

(Not absolute limitation)

- It is tentatively assumed that fuel debris will be transferred into concrete cell by using a cask. Sample preparation will be roughly performed in concrete cells.

- In iron cells, precise sample preparation, chemical separation and so on will be carried out.

- In grove box and hood, radioactivity analysis, chemical analysis, physical and so on will be carried out.

Laboratory-2 should have much flexibility for various analyses because incentive of fuel debris analysis is not established well.
Advanced technology to be applied (1)

**Radioactivity measurement**

- For both laboratories, the characteristic and inventory evaluations of radioactive wastes will be performed by mainly radioactivity measurements and it is needed to carry out the accurate measurement.

- But there is a possibility of including high-level background to the experimental data because air dose rate in 1F site is relatively high due to the released radioactive materials by fuel failure.

- Therefore, intake air will be purified through high performance filters and the whole buildings will have a positive pressure against the outside.

- This allows to keep the high sensitivity of the radioactivity measuring apparatus to be installed.
Advanced technology to be applied (2)

- **Identification of received sample (Laboratory-1)**
  - Even though low dose radioactive wastes will be treated by hand work in a sealed house, it is too difficult to identify the analysis position from especially the large size wastes due to uncertain contamination distribution on the materials.

  - Currently, gamma camera device which can allow non-destructive test and visualization of radioactive nuclides has been already developed, but the resolution is not good.

  - If the resolution is improved, the identification of analysis position would be simply determined.

  - Therefore, the development and improvement will be positively performed toward the application of high-performance gamma camera device.
Identification of received sample (Laboratory-2)

- Debris is assumed to be enclosed in a metal container. It is considered that especially fuel debris will be formed in an inhomogeneous mixture with concrete and core/structural material, therefore it seems to be difficult to identify the analysis position by looks.

- As one of the PIE techniques, X-ray CT scan technique has been applied to non-destructive test of fuel assembly of fast breeder reactor. This technique has a high resolution and can permit the visualization of thick samples.

- This technique will be installed by taking account of not only penetrative power of X-rays to fuel debris and container but also the removal method of fuel debris from metal container after the X-ray CT scan test.
Conclusion

- As one of decommissioning projects for Fukushima Daiichi Nuclear Power Plant, it is planned that Japan Atomic Energy Agency will construct new facilities for analysis and research of radioactive wastes such as rubbles, secondary wastes and debris.

- In Laboratory-1, radioactive wastes such as rubbles and secondary wastes will be mainly treated. Detail design is under way, and the operation will be started from 2018.

- In Laboratory-2, radioactive wastes such as high dose rubbles and secondary wastes will be treated. Debris such as fuel debris and high dose reactor core/structural materials will be also handled. Detail design will be started soon and the operation will be started until the beginning period of fuel debris removal.

- The introduction of advance technology to each laboratory and the improvement of non-destructive devices to both laboratories is positively under consideration, which will contribute to the acceleration of decommissioning projects.
Thank you for your attention.