Outline of Japan Atomic Energy Agency's Okuma Analysis and Research Center (2) - Laboratory-1 -

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Abstract

Decommissioning of Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Station is in progress according to the Japanese Government's "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station". Radiometric analysis of fuel debris and radioactive wastes such as contaminated rubble and secondary wastes from water processing is needed for the decommissioning. The Roadmap assigned the construction of a hot laboratory to the Japan Atomic Energy Agency. The hot laboratory, "Okuma Analysis and Research Center", will be constructed near the Fukushima Daiichi Nuclear Power Station site.

Okuma Analysis and Research Center consists of the three buildings; Administrative building, Laboratory-1 and Laboratory-2. In particular, Laboratory-1 will provide the analytical data needed to establish the strategy and methodology for treatment and disposal of low and medium level radioactive wastes from Fukushima Daiichi Nuclear Power Station site.

1. Introduction

The nuclear accident at Fukushima Daiichi Nuclear Power Station (hereinafter, referred to as "1F") operated by the Tokyo Electric Power Company occurred due to the large scale earthquake and resulting tsunami on March 11, 2011 [1,2]. Decommissioning of 1F is in progress at the initiative of the Japanese government after the accident. The Japanese government established the "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station" (hereinafter, referred to as "the Roadmap") in order to show the basic principles and the main target processes for decommissioning of 1F [3]. Various efforts such as fuel retrieval from spent fuel pools, waste management, and research and development have been currently undertaken in line with the Roadmap.

To proceed with the decommissioning, the Roadmap has taken up the issue of processing and disposal for radioactive wastes generated by 1F accident. It is not easy to carry out processing and disposal because there is a wide range of wastes which are unclear about the characteristics. In order to manage the radioactive wastes in future, it is necessary to create the guidelines for processing and disposal of the radioactive wastes. Therefore, it is essential to analyze the radioactive wastes to obtain information on the characteristics such as radioactive substances, chemical and physical properties.

The Japan Atomic Energy Agency has been currently constructing the research and development facilities to solve the issue based on the Roadmap. The facilities, "Okuma Analysis and Research Center", have been building near 1F site so as to analyze a large number of samples rapidly.

Figure 1 shows the expected completion drawing of the Okuma Analysis and Research

Center [4]. The Okuma Analysis and Research Center has three buildings; an administrative building, Laboratory-1, and Laboratory-2. The administrative building has researcher's offices, meeting rooms, and a workshop. Laboratory-1 will provide information on low and medium level radioactive wastes such as rubble and secondary wastes. Laboratory-2 will provide information on fuel debris and high level radioactive rubble and secondary wastes.

This document outlines the concept of Laboratory-1 in the Okuma Analysis and Research Center with a focus on the research plan.

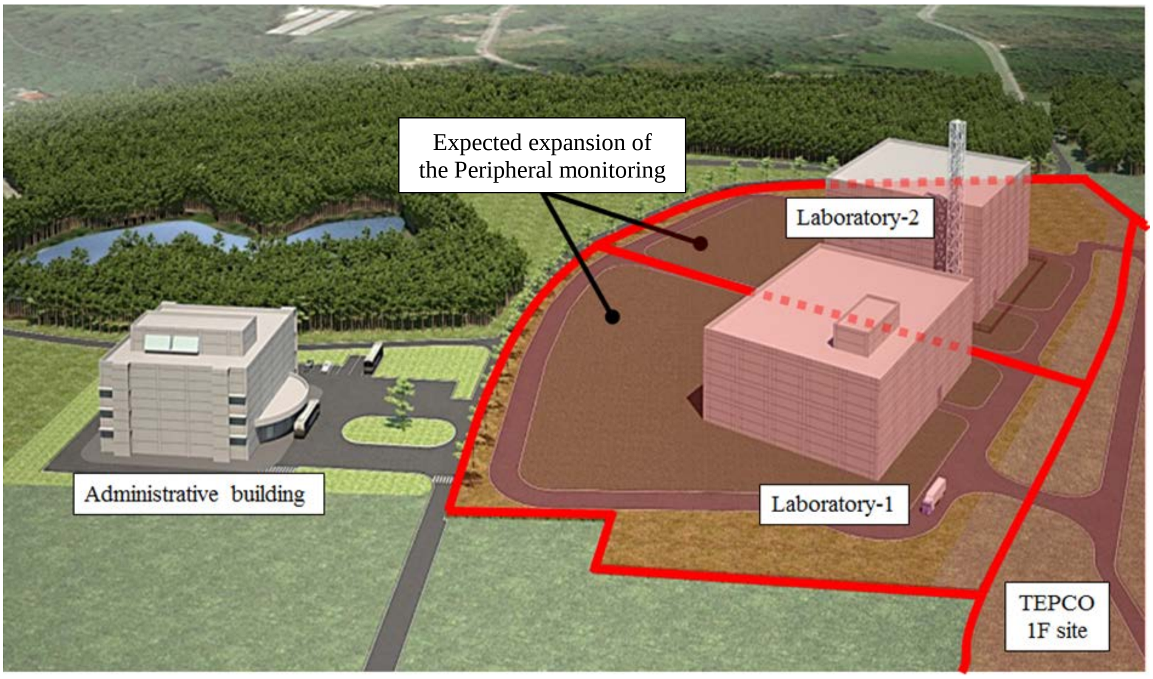

Fig. 1. Okuma Analysis and Research Center (expected completion drawing)

2. Objects of analysis

Laboratory-1 will be used to analyze low level (< 1 mSv/h) and medium level (≤ 1 Sv/h) samples*[1]. The objects of analysis are mainly rubble which is scattered in 1F site, incineration ash and secondary wastes from water processing. The maximum weight of low level samples is about 300 kg, and the maximum size will be the limit to pass through the doors of Laboratory-1. The maximum weight of medium level samples is about 2 kg, and the maximum size is the samples that can be handled with slave manipulator in the steel hot cells.

Table 1 shows the objects of analysis and the details in Laboratory-1. A large fraction of rubble remains in the reactor buildings and a minor fraction has been cleared and stored outside the reactor buildings. Trees with branches, leaves, roots, and soil generated by land clearance for construction of new facilities at the 1F site are stored in temporary storage facilities on the site. Incineration ash is produced by incineration of radioactive wastes such as protective clothing and felled trees. Secondary wastes from water processing are sludge, slurry, adsorbent, and processing water from desalination apparatus. These secondary wastes are produced through water processing systems (KURION, SARRY, and ALPS) which remove radioactive materials from contaminated water and coolant of the nuclear reactor. These samples are pretreated at steel hot cells, glove boxes, fume hoods, and a sealed room so as to measure the target analyte. After pretreatment, the samples are measured by using analytical apparatus.

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*[1] The definitions of low and medium levels are internal to this site only and are not in agreement with international or Japanese accepted definitions of waste levels.

Table 2 shows the details of target analyte at the present stage. It was determined that for safe disposal of 1F wastes that 38 radioactive nuclides and harmful substances should be assessed. In order to save time and labor for separation of analyte, multiple nuclides will be measured at the same time by using analytical apparatus such as ICP-MS (inductively coupled plasma mass spectrometer). The obtained data will contribute to create the guidelines for treatment and disposal of the radioactive wastes from 1F.

Table 1. Objects of analysis and the details in Laboratory-1

Objects of analysis	Sources	Details
Rubble	Building rubble	Concrete, Metal
	Plants	Felled trees, branches, leaves, and roots
	Soil	Surface soil from the 1F site
Incineration ash	Ash generated from incineration of radioactive wastes	Incineration ash of radioactive wastes such as protective clothing and felled tree
Secondary wastes from water processing	Sludge and Slurry	Deposits of Barium sulfate and Nickel ferrocyanide, Slurry of Iron hydroxide and Carbonate
	Adsorbent	Activated carbon, Titanate, Ferrocyanide, Titanium oxide, chelating resin, etc.
	Processing water from desalination apparatus	High concentration salt water and Wastewater
	et cetera	Reverse osmosis membranes

Table 2. Details of target analyte about each object (1/2)

Analysis items	Target analyte	Objects of analysis
Radioactive nuclides	^{3}H, ^{14}C, ^{36}Cl, ^{41}Ca, ^{59}Ni, ^{60}Co, ^{63}Ni, ^{79}Se, ^{90}Sr, ^{93}Zr, ^{94}Nb, ^{99}Tc, ^{107}Pd, ^{126}Sn, ^{129}I, ^{135}Cs, ^{137}Cs, ^{151}Sm, ^{152}Eu, ^{154}Eu, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{243}Am, ^{244}Cm, ^{242m}Am, ^{245}Cm, ^{246}Cm	Rubble, Incineration ash, Secondary wastes from water processing
Harmful substances	Chlorine	Rubble, Secondary wastes from water processing
	Sulfur	
	Bromine	
	Iron	
	Sodium	
	Magnesium	
	Calcium	
	Potassium	
	Strontium	
	Chemical form	Rubble

Table 2. Details of target analyte about each object (2/2)

Analysis items	Target analyte	Objects of analysis
Harmful substances	Asbestos(RCF)	Rubble, Incineration ash
	pH	Secondary wastes from water processing
	Oil content(n-hexane extract)	Rubble
	Boron and its compounds	Rubble, Incineration ash, Secondary wastes from water processing
	Cyanide	
	Polychlorinated biphenyl	Rubble
	Lead and its compounds	Rubble, Incineration ash, Secondary wastes from water processing
	Cadmium and its compounds	
	Organophosphorus compounds	
	Hexavalent chromium compounds	
	Arsenic and its compounds	
	Mercury and its compounds	
	Selenium and its compounds	
	Fluorine and its compounds	
	Ammonia, Ammonia compounds	
	Nitrites, Nitrates	
	Suspended solids	
	Copper	
	Zinc	
	Soluble iron	
	Soluble manganese	
	Total chromium	
	Nitrogen	
	Hydrogen	
	Hydrogen Cyanide	Secondary wastes from water processing

3. Analytical process

3.1 Analytical methods and apparatus

Analytical methods in Laboratory-1 are radiochemical analysis, chemical composition analysis, and mechanical and physical property measurement.

(1) Radiochemical analysis
Radiochemical analysis provides information on radioactivity such as radionuclide concentration data in wastes needed to treat and dispose, and information on chemical states that affect the transfer coefficient in soil.

(2) Chemical composition analysis
Chemical composition analysis provides information on co-existing substances for the solidification of radioactive wastes and harmful substances that may affect the environment.

(3) Mechanical and physical property measurement
Mechanical and physical property measurement provides information on strength evaluation of building structures in 1F, and physical property data for treatment and disposal wastes.

Table 3 shows the relationship between target analyte and analytical apparatus in Laboratory-1. There are a large variety of the analyte, and in many cases the analyte to be analyzed are unevenly distributed in the samples. The variety and distribution of analyte require an enormous amount of samples to accurately describe the strategy and methods for

1F wastes treatment and disposal.

Table 3. Relationship between target analyte and analytical apparatus in Laboratory-1

Analysis items	Apparatus	Data to be acquired (Target analyte)
Radioactivity	Liquid scintillation counter	Low-energy β-emitter radioactivity (H-3, C-14, Ni-63, Se-79, Sr-90, Zr-93, Mo-93, Tc-99, Pd-107, Sn-126, Sm-151)
	γ-ray spectrometer (HPGe detector)	γ-emitter radioactivity (Co-60, Nb-94, Cs-137, Eu-152,154)
	γ-ray spectrometer (Ge-LEPS detector)	Low-energy γ-emitter radioactivity (Ni-59)
	γ-ray measuring device (NaI (Tl) scintillation counter)	Separation confirmation
	α-ray spectrometer	α-emitter radioactivity (U-233,234, Pu-238,239,240,242, Am-241,243, Cm-244)
	Gas-flow counter	β-emitter radioactivity (Cl-36, Ca-41)
Elemental analysis	Inductively coupled plasma atomic emission spectrometer (ICP-AES)	Trace metal elements concentrations
	Inductively coupled plasma mass spectrometer (ICP-MS)	Actinide nuclide concentration (I-129, Cs-135, U-235,236,238, Np-237, Pu-241, Am-242m, Cm-245,246)
	Atomic absorption spectrometer	Trace metal element concentration
Salinity	Ion chromatograph	Chlorine concentration
Organic matter	Total organic carbon analyzer	Organic matter concentration
Surface	Scanning electron microscope / energy dispersive X-ray spectroscopy (SEM-EDX)	Surface chemical composition
	Digital microscope	Surface condition
Chemical analysis	Ultraviolet-visible spectroscope	Toxic element concentration
Hydrogen gas	Gas chromatograph	Hydrogen gas concentration
Mechanical characteristics	Tensile and compression test equipment	Stress of structural materials
Specific surface area / Particle size distribution	Surface area analyzer	Specific surface area of pulverized sample
	Particle size distribution measuring device	Particle size distribution of pulverized sample

3.2 Layouts of Laboratory-1

Figure 2 shows the layouts of Laboratory-1. The first floor has ventilation equipment, emergency generators, a truck area room, and temporary storage of radioactive solid and liquid wastes. The second floor has access control equipment for analysts, a sealed room, steel hot cells, glove boxes, and fume hoods. On the third floor, there is a test room, the facility control room and an emergency room. Currently, Laboratory-1 has been in the construction phase and will start operation in the spring of 2020.

Laboratory-1 will have 4 steel hot cells, 10 glove boxes, 50 fume hoods at the beginning of operation, and spare space is reserved to add 2 steel hot cells and 50 fume hoods. The roles of each equipment are described as follows. The steel hot cells are used to handle medium level samples which have a high risk of scattering. The steel hot cells accept medium level rubble and secondary wastes from water processing (≤ 1 Sv/h, < 2 kg), and transfer the samples to glove boxes after pretreatment. The glove boxes are used to handle low level samples which have a high risk of scattering. The glove boxes are classified into two groups. One group pretreats samples while another measures mechanical and physical properties. The former group transfers the samples to fume hoods after pretreatment of the samples. The fume hoods are used to pretreat samples for radiochemical analysis chemical composition analysis.

In the test rooms, these pretreated samples are measured by analytical apparatus. The test rooms are on the third floor so as not to be interfered with the analysis by radiation which is emitted by radioactive materials on the ground from 1F accident.

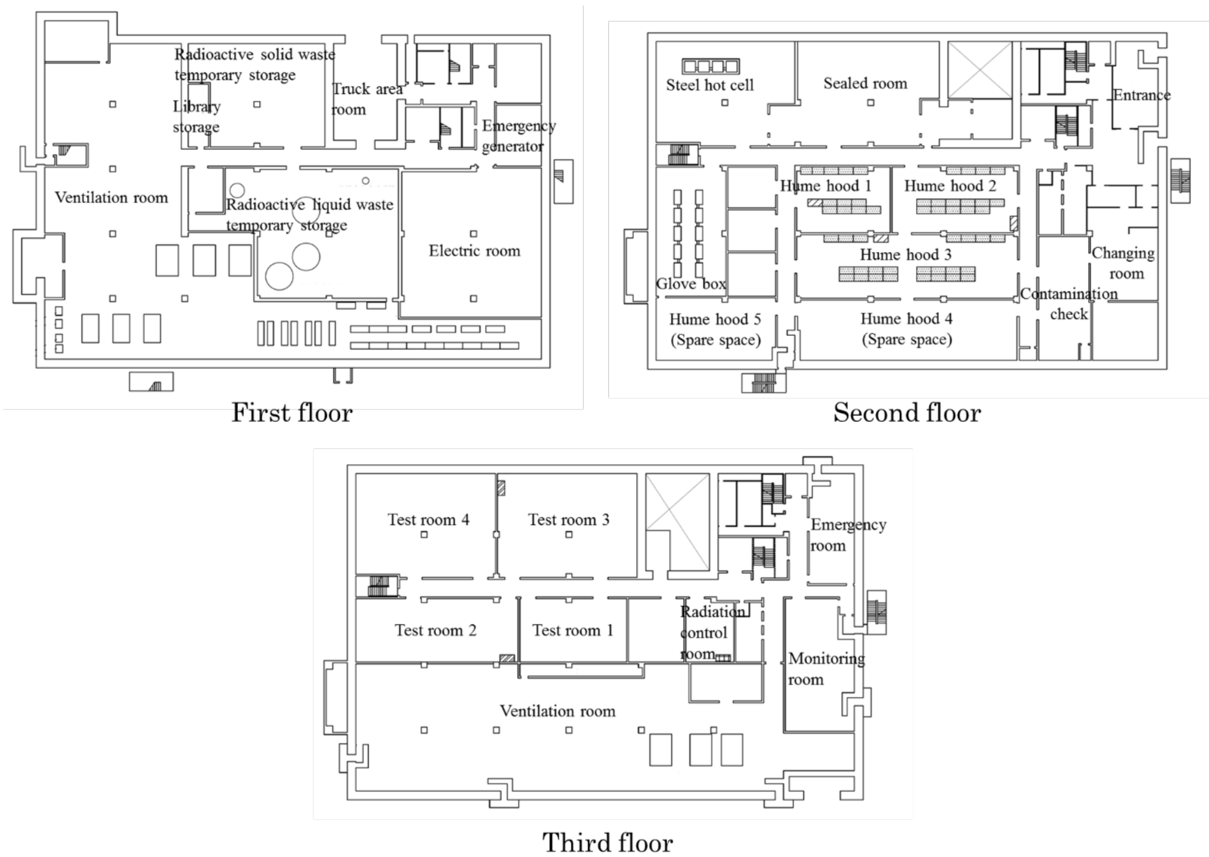

Fig. 2. Layouts of Laboratory-1

3.3 Analytical procedures

Figure 3 shows the analytical flow chart in Laboratory-1. The samples accepted from 1F are transported to Laboratory-1 by truck. In the truck area room, an overhead crane carries the samples to the second floor. The samples are categorized according to differences of size and radiation level, and transferred to a sealed room or steel hot cells.

Low level samples are transferred to a sealed room. In the sealed room, sample preparation is carried out. For example, the samples are coarsely crushed by using rough processing equipment such as a core drill machine. The prepared samples are subsequently divided/measured and distributed to glove boxes and fume hoods. When the samples have a high risk of scattering, these samples are distributed to glove boxes, and then performed pretreatment such as pulverization and subdivision. When the samples have a low risk of scattering, these samples are distributed to fume hoods, and then performed pretreatment such as pulverization, dissolution and separation.

Medium level samples are transferred to steel hot cells. In the steel hot cells, the samples are processed and pulverized, and then the glove boxes accept the samples. After the subdivision of the samples in the glove boxes, the samples are transferred to fume hoods so as to perform pretreatment such as dissolution and separation.

These pretreated samples are measured with analytical apparatus. In the test rooms, radiochemical and chemical composition analysis are performed. In the glove boxes and fume hoods, mechanical and physical property measurement are performed.

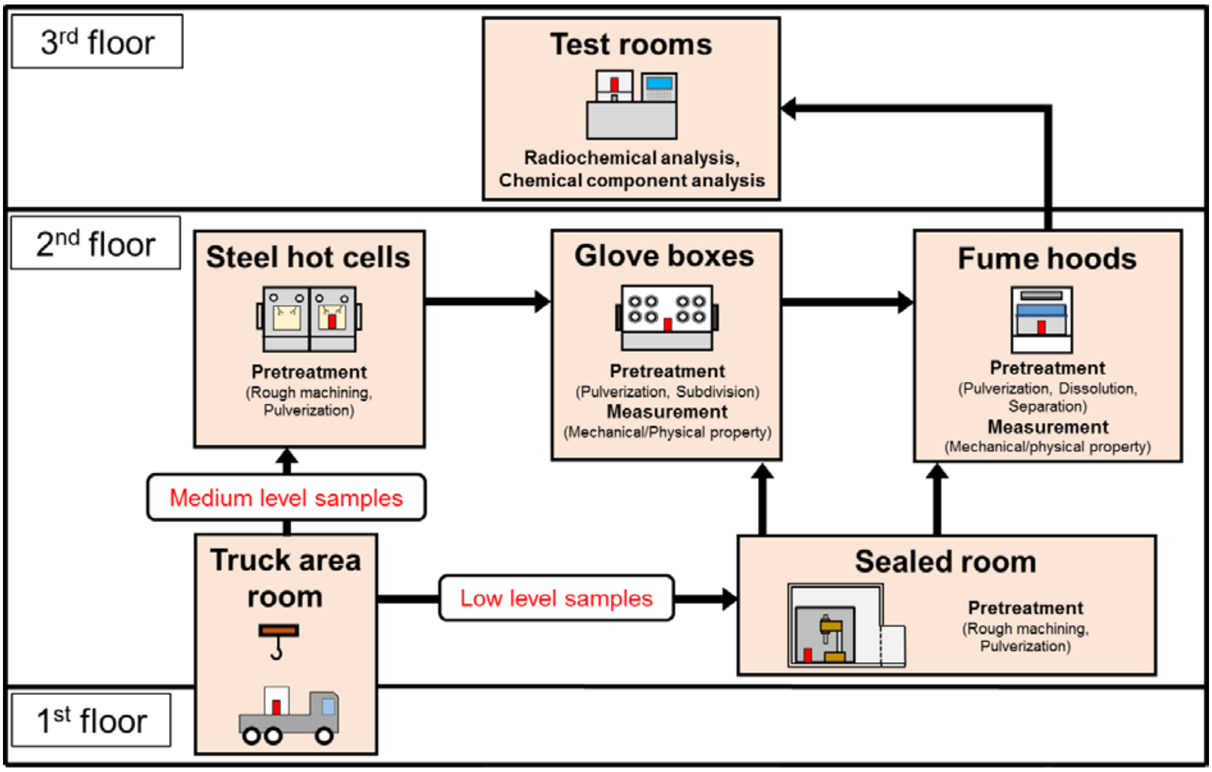

Fig. 3. Analytical flow chart in Laboratory-1

4. Summary and Future Work

The Japan Atomic Energy Agency has currently developed “Okuma Analysis and Research Center” in line with the Roadmap towards decommissioning of 1F. Laboratory-1 in Okuma Analysis and Research Center is currently in the construction phase and will start operation in the spring of 2020.

In order to analyze the samples smoothly and accurately, it is necessary to further improve efficiency and labor saving of analysis procedure and develop human resource for analysis. We have attempted to develop technology for operation with the construction, such as simplification of analytical methods.

When starting operation, Laboratory-1 will significantly contribute to safely execute decommissioning of 1F.

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