Learning analytical works on radioactive wastes

Towards environmental restoration of Fukushima and decommissioning

In order to promote understanding of nuclear energy and to contribute to human resource development in the field of nuclear energy (in particular, including research related to the decommissioning), Japan Atomic Energy Agency (JAEA) holds internships for students during the summer vacation every year. JAEA recruits students who want to participate in this internship by setting versatile programs in wide range of themes including hands-on trainings. Such continuous efforts have promoted the relationship between JAEA and universities/colleges all over Japan, and strengthened the mutual cooperation and collaboration systems.

In the Okuma Analysis and Research Center[*1)] (hereafter referred to "Okuma Center"), Sector of Fukushima Research and Development, JAEA, the summer internship was conducted this year while taking all possible measures to prevent new coronavirus infections. Before accepting students, careful preparations were made such as conducting antigen tests in advance.

In line with the medium-to-long term roadmap formulated by the government, the decommissioning is now being progressed every day at the Fukushima Daiichi Nuclear Power Station (hereafter referred to "1F"), Tokyo Electric Power Company Holdings, Inc. At the Okuma Analysis and Research Center that is located next to the 1F, the practical training was held from September 27 (Mon) to October 1 (Fri), 2021 under the theme of

“Practical training on manipulator, glovebox and analytical instruments”. In this training, one graduate student of Ibaraki University Graduate School participated.

■First of all, let the student get to know the present status of the recovery from the nuclear disaster and the situation of the 1F site correctly.

On the first day of the training, Mr. Nakai, Director General of the Okuma Center, made an opening speech. Then, lectures were presented on the following topics: 1) the outline of JAEA, 2) the organization and the research contents of JAEA, 3) the roles of JAEA and Sector of Fukushima Research and Development for the 1F decommissioning, 4) the contents of research and development conducted at each Center of the Sector, and 5) the future image expecting young researchers who will bear the next generation.

After that, the student visited “The Great East Japan Earthquake and Nuclear Disaster Memorial Museum”. This museum opened in 2020, just ten years after the 1F accident, aiming for letting people know the history of the Fukushima restoration in these ten years. In the museum, the student had a look around the situation of the Tsunami disaster at that time. He also had a look around the correspondence to the nuclear disaster that had been changing from moment to moment, the disaster correspondences by the government and local governments, changes in the evacuation statuses, and the activities towards the environmental restoration and recovery. From the window of the round-trip train, the student was able to directly experience the reconstruction of the Hamadori District.

On the next day, there was a lecture on “Radiation Safety and Protection” that is a basis for safely operating facilities where radioactive materials are treated. Then, practical training was conducted inside and outside the Facility Administration Building where radiation measurement instruments are actually used as a radiation management task. The contents of the training were, 1) radiation dose measurements using an NaI scintillation counter[*2)], 2) smear tests[*3)] using a GM survey meter, 3) measurements of radioactive material concentration in atmospheric floating dust using a dust sampler[*4)] (right photograph), and so forth.

Next, the student compared radiation doses measured with the monitoring post (adjacent to the north side of the Facility Administration Building) located at the surveillance area just after the accident with the current radiation doses after the radiation decay. Based on the measurement results, he estimated how are the measured radiation doses compared with those in his living place. Further, the student came to know that the currently working area is safe, by understanding the meaning of the actually measured values based on the calculation of the annual radiation exposure. In addition, he was let understand correctly the road to the reconstruction of Fukushima so far such as the decommissioning/decontamination, and the status of interim storage facilities that are progressed at the off-site. The student said, “I had felt that the information and explanation about Fukushima reconstruction were fragmentary. But after this training, I was able to correlate various kinds of information. Also, I could fully understand the actual situation of current radiation doses.”

■Understanding the daily efforts aiming for the improvement of analytical technology towards the steady promotion of the decommissioning.

Next, the student experienced the main subject, that is, the analytical works. First, the students learned the role and functions of the mock-up iron cell and the glovebox at the workshop in the facility administration building. Then, he experienced to operate them by himself. In the training for the iron cell, the operation had to be conducted by remote control using a manipulator. Therefore, at the beginning, the student seemed not to be able to move the tools in the cell as he wanted. But owing to the advises by the JAEA staff, the student seemed to come to get used to operate the manipulator, and finally he seemed to enjoy handling the manipulator in the cell as if it is his own arm (upper photograph).

The Building No. 1 is now under construction, so analysis of radioactive wastes cannot be currently conducted in the building. Assuming that the operation has actually started, the student entered the Building No.1 from the radiation checking area where a body surface radiation monitor and an entry/exit checking device are installed. Then, the student had a look around the facility in line with the analytical flow, from carrying in/out of samples and sample preparation to measurements. As to sample preparation, he toured the panel house room, iron cells where high-level radioactive materials are treated, glove boxes for medium-to-low level radioactive materials, and fume hoods for analytical procedure (right photograph).

At the end of the tour, the student visited the measurement room where radioactivity concentration etc. are measured. There, the JAEA staff in charge explained in detail about each instrument such as ICP-MS[*5)], HPGe[*6)], liquid scintillation counter[*7)], and IC/GC[*8)]. The student actively asked questions while earnestly listening to the explanations (opening photograph).

Furthermore, the student visited the Collaborative Laboratories for Advanced Decommissioning Science (CLADS) where research and development towards the upgrading of analytical technology is being conducted. In the CLADS, the student learned the measurement of recovery rate for molybdenum using ICS-MS[*9)] and separation test of selenium using solid-phase extraction[*10)].

Through the visit, the student seemed to be impressed to see that many JAEA staff are working on the development of analytical technology while cooperating with each other towards the future full-scale analytical works at the Building No. 1. Also, he was looking seriously at the JAEA staff who carefully proceeded the analytical tests while checking each procedure one by one (left photograph).

■After the training ～The student was surprised to see many young staff were actively working at the real site of the restoration of Fukushima～

In this summer internship, the student was able to experience more realistic trainings. For example, the student confirmed instruments and measurement apparatuses that are actually used in analytical works at the real site. In addition, for some of the instruments, the student was able to operate them by himself. Before making the final training report, there was an opinion exchange with the staff in the analysis section about their experiences in each analytical works. Also, the time was set to exchange advices and encouragements from the senior staff who graduated the same university as the students.

At the end of the training, the student presented the summary of the contents that he had learned in five-day training. Based on that, he talked with the staff about "the impression after the training". Then, the student expressed the following opinions and his future plans.

－Tomoyuki Saito, Ibaraki University Graduate School

I am studying effects of radiation on cells in the Ibaraki University Graduate School. When I was in the 4th year of the university, I came to be deeply interested in the restoration of Fukushima, because at that time I was studying the measurements of radioactive cesium in forests and mountain soil at the difficult-to-return zone of Namie Town. I think that the works related to Fukushima, especially analysis of nuclear fuel debris that is essential to proceed the decommissioning, is quite important. I want to be engaged in the works at the Okuma Center even a little. I hope to make efforts towards the completion of the 1F decommissioning.

I strongly believe that when the decommissioning works proceed and will be completed in future, the restoration of Fukushima will be surely accomplished.

The Okuma Center is now highly expected from various fields, so we will further work on the research/development and upgrading of analysis towards the future progress in the 1F decommissioning. Also, we will work together on the various tasks such as the speedy development of the obtained knowledge. In addition, the Okuma Center will continue the efforts for the development of human resources that will bear the next generation while deeply recognizing its importance.

[Terminology]

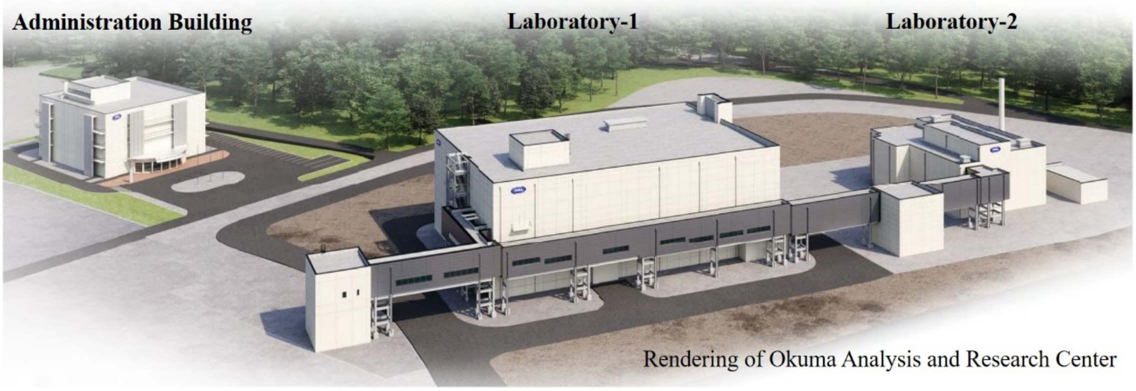
***1) Okuma Analysis and Research Center**

The Okuma Analysis and Research Center is an organization belonging to the Fukushima Research Institute, Sector of Fukushima Research and Development, JAEA. In the Center, the "Facility for Analysis and Research of Radioactive Materials" composed of the following three facilities are being prepared.

・"Administration Building" composed of office rooms, meeting rooms, workshop, etc. It is used to contribute to smoothly conduct design, construction and operation of the Laboratory-1 and Loaboratory-2 (started operation in march 2018).

・"Laboratory-1" for the analyses of medium-to-low level debris, incinerated ash, and secondary wastes of contaminated water (under construction).

・"Laboratory-2" for the analyses of high-level radioactive materials including nuclear fuel debris (in approval procedure).



Rendering of Okuma Analysis and Research Center

***2) NaI scintillation counter**

An apparatus to measure radiation in which sodium iodide (NaI) is used in the γ-ray detection part. Since the accuracy and the sensitivity are high, it is suitable to measure air dose rates of γ-rays from environmental level to about 10 μSv/h.

***3) smear measurement method**

A method to measure radioactivity contamination on surface. First, surface of a sample is wiped out by a special paper called smear filter paper. Then, the concentration per unit area of radioactive materials (mainly focusing on β-rays that are easy to be absorbed) attached (contaminated) on the surface is measured by a GM survey meter.

***4) measurements of radioactive material concentration in atmospheric floating dust using dust sampler**

Atmospheric floating dust is collected on a special filter paper by sucking a certain amount of air using a low-volume air sampler (aspirator). Then, the concentration of radioactive materials (ca. Cs-137) in atmosphere is determined from the filter paper using various kinds of radiation measurement devices.

***5) ICP-MS**

It is an abbreviation of Inductively Coupled Plasma Mass Spectrometry. Liquid sample is first nebulized using an inductively coupled plasma (ICP) produced by applying high-frequency power to argon gas as an ion source. Then, elements in the sample that was ionized by the plasma are separated/detected by a mass spectrometer (MS).

Since single mass spectrometer is used in this measurement system, the ionized components are directly detected. For this reason, it is sometimes difficult to analyze nuclides that have the same mass, and molecules.

***6) HPGe**

A high-purity germanium semiconductor detector with which various kinds of γ-rays can be accurately measured owing to its high spectral resolution.

***7) liquid scintillation counter**

A radiation detector where amount of radioactivity (mainly β-rays emitting nuclides) in liquid is measured using liquid scintillator (luminescent agent).

***8) IC/GC**

"IC" is an abbreviation of ion chromatography, which is an instrument to conduct separation and qualitative/quantitative analysis of ions in liquid sample. "GC" is an abbreviation of gas-flow counter. In GC, gas is circulated in the instrument at a constant flow rate, and the number of particulate radiations emitted to the hemispherical space with a solid angle of 2π in a unit time is measured. GC is mainly used to measure β-ray emitting nuclides.

***9) measurement of recovery rate for molybdenum using ICS-MS**

Radioactive molybdenum (Mo-93) is one of the fission products (FP), which are produced by the fission of uranium. Compared with the other FP's produced by the 1F accident such as Cs-137 and Sr-90, the production rate of Mo-93 is considerably low and its half-life is long. For such long half-life nuclides, many analytical methods have been attempted so far using mass spectrometers with high sensitivity. However, even now there still remains difficulty in the analysis such as the difficulty in the separation of isobars (nuclides that have the same mass but different atomic number). Therefore, in order to efficiently separate zirconium (Zr), niobium (Nb) and molybdenum (Mo) that are the isobars of mass number 93, an analytical method using ZR resin has been further developed. In this method, Zr and Nb are eliminated by sequentially adding oxalic acid with different concentration into the column containing the mixture. Using this method, the test is conducted by measuring how much target molybdenum was recovered.

***10) separation of selenium using solid-phase extraction**

Like Mo-93, the half-life of selenium (Se-79) is so long that an analytical method using mass spectrometer with high sensitivity has to be used. However, bromine (Br-79 that is a stable nuclide) that is the isobar of Se-79 is needed to be separated.

For the separation of Br-79, it was concerned that the analytical procedure may become complicated because generally solvent extraction must be repeated. In order to solve this problem, a new solid-phase extraction method has been investigated where solvent is adsorbed on the surface of particles with high separation function. As a result, a new method to surely conduct the separation to be needed has been developed.

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