8 Research and Development Related to the Accident at TEPCO's Fukushima Daiichi NPS

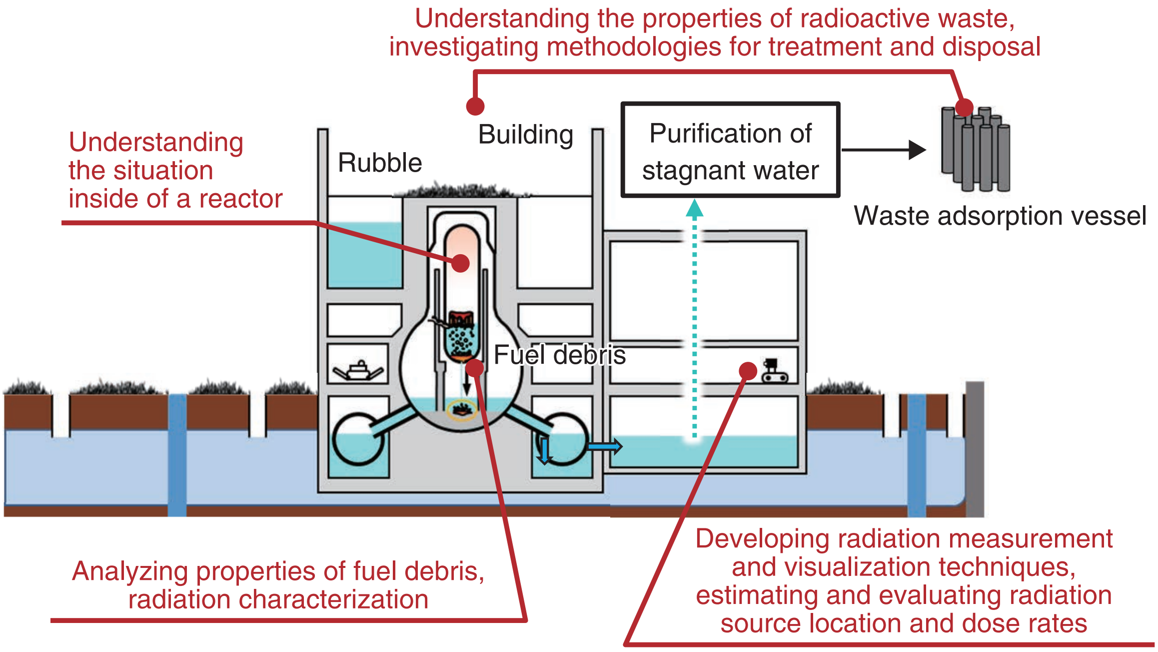

Fig.1 Schematic diagram of research and development (R&D) for decommissioning of the TEPCO's Fukushima Daiichi Nuclear Power Station (FDNPS)
Toward the decommissioning of the FDNPS, the JAEA is conducting R&D on the safe and reliable implementation of operation processes on the topics "understanding the situation inside of a reactor," "analyzing properties of fuel debris," "radiation characterization," "developing radiation measurement and visualization techniques," "estimating and evaluating radiation source location and dose rates," "understanding the properties of radioactive waste," and "investigating methodologies for treatment and disposal."

The JAEA is promoting safe, reliable, and rapid decommissioning processes (for e.g., fuel debris extraction) that are technically challenging. In addition, the JAEA is engaged in surveys and research and development (R&D) for environmental restoration to create a safe and secure living environment for the inhabitants. These initiatives are conducted via co-operation and collaboration between the other R&D sectors, and they leverage the skills, knowledge, and experience developed over the years. The JAEA will use the technologies, knowledge, and experience that we have accumulated through decommissioning for back-end measures of nuclear facilities and share them widely with the rest of the world to contribute to the improvement of safety at nuclear facilities in various countries.

R&D for decommissioning the FDNPS

The three facilities located in Hamadori area on the Pacific coast of Fukushima, namely, the Collaborative Laboratories for advanced Decommissioning Science (CLADS), Naraha Center for Remote Control Technology Development (NARREC), and Okuma Analysis and Research Center, are parts of the Fukushima Innovation Coast Initiative (field of decommissioning). The Initiative is a national project that aims to build a new industrial base in the Hamadori area to restore the industries that were lost due to the Great East Japan Earthquake and the nuclear disaster. We conduct R&D on decommissioning, etc., according to our specified roles. As a part of R&D on decommissioning, we mainly worked on R&D related to fuel debris retrieval, accident progression scenario analysis, treatment and disposal of radioactive waste, remote control technology, etc., and contributed to the TEPCO's Fukushima Daiichi Nuclear Power Station (FDNPS) decommissioning (Fig.1).

It is important to understand the situation inside a reactor to remove the fuel debris. To assess the physical, chemical, and biological aging of the fuel debris more than a decade after the FDNPS accident, the situation after the Chornobyl Nuclear Power Plant accident was reviewed and its effects assessed (Topic 8-1).

In decommissioning operations, the radiation properties of fuel debris should be clarified for safe handling of the debris. Therefore, an evaluation method for dose rates from bremsstrahlung X-rays generated by fuel debris was investigated (Topic 8-2).

In addition, knowledge of the type, dose rate, and distribution of radiation is important to reduce exposure to workers during decommissioning operations and to plan the decommissioning process. Therefore, a method was devised to simultaneously identify and measure the position of ^{137}Cs and ^{90}Sr/^{90}Y using an optical fiber with a liquid core material (Topic 8-3). In addition, a method was developed to automatically estimate structure information from point cloud data using deep learning to determine the exact radiation dose rate distribution in a workspace (Topic 8-4). Furthermore, the behavior of Cs in nuclear reactors and buildings was elucidated by improving the code for analyzing Cs behavior and experimentally clarifying the adsorption behavior on nonferrous structural materials (Topics 8-5 and 8-6).

To assess the risk of combustion/explosion of the hydrogen generated by the radiolysis of the water present in high-dose radioactive waste in storage, numerical analysis and simulation methods for hydrogen leakage/diffusion behavior and combustion/explosion were developed (Topics 8-7 and 8-8). Furthermore, an analytical method was developed to evaluate the cooling conditions resulting from air cooling when the supply of the cooling water is stopped during fuel debris extraction (Topic 8-9).

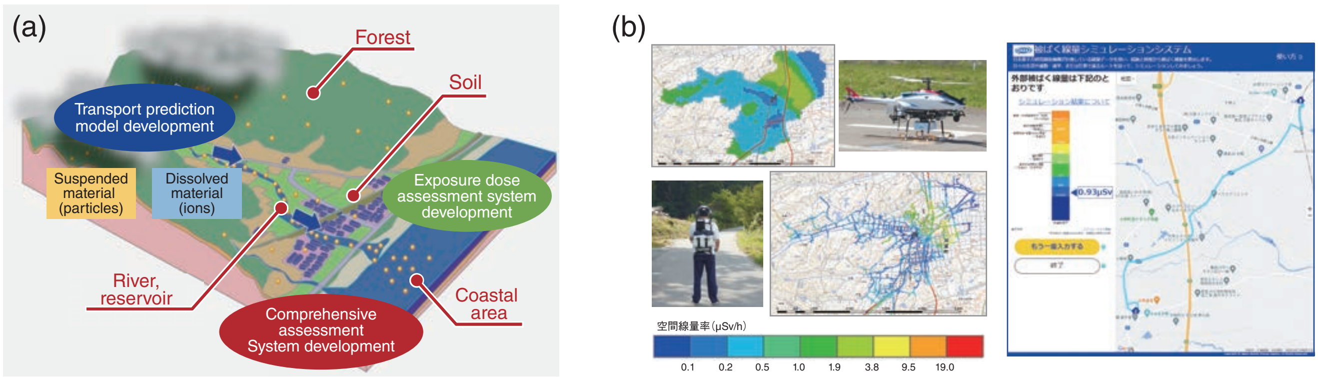

Fig.2 Schematic diagram of the environmental dynamic studies and environmental monitoring and mapping
(a) As a part of "Environmental Dynamics studies," radioactive material surveys are performed across areas, from forests and rivers to sea areas, and the results are used to develop prediction models of the transport of radioactive material and systems for assessing exposure doses. (b) As a part of the "Development of environmental monitoring and mapping techniques," techniques for measuring radiation dose distribution using unmanned aerial vehicles and walking surveys are being developed. The results are used to develop a simulation system for assessing exposure doses.

R&D for environmental restoration

The CLADS research base has been established in the Fukushima Prefectural Centre for Environmental Creation Research Building (Miharu Town) and the Environmental Radiation Monitoring Centre (Minamisoma City), and collaboration and co-operation have been established between the Fukushima Prefecture, National Institute for Environmental Studies, and JAEA. The JAEA is engaged in R&D related to environmental restoration, including environmental dynamics research and the development of monitoring and mapping technologies (Fig.2).

In the field of environmental dynamics research, we focus on radioactive Cs, and clarify its behavior in the environment, including its migration, accumulation, and transfer to the ecosystem, and present our scientific findings in an easy-to-understand manner. This contributes to eliminating anxiety among residents, formulating plans for the lifting of the evacuation order by local authorities, and restoring agriculture, forestry, and fisheries. Since the environment may also include other radionuclides besides ^{137}Cs, methods for analyzing these radionuclides are required.

As most of the radioactive Cs released into the environment is present in contaminated forest areas, it is necessary to clarify how it is transferred to rivers. In particular, to explain the formation of dissolved Cs, which plays an important role in its transport to ecosystems, Cs run-off phenomena were elucidated by incorporating the elution of Cs from organic matter such as fallen leaves and branches in forested areas into a basin water cycle model, in addition to its desorption from soil particles (Topic 8-10). As the behavior of ^{137}Cs diffluence differs with land use, a prediction model that considers the characteristics of the land was used to predict the behavior of Cs up to 30 years after the FDNPS accident (Topic 8-11).

In reservoirs and coastal areas where river water or sediments containing ^{137}Cs entered the water, it is important to understand the mechanism, as leaching from the sediment into the water and resuspension of sediment may affect aquatic life. Therefore, the behavior of ^{137}Cs dissolution from the sediment was considered by examining the concentration of ^{137}Cs and coexisting ions in the water and sediment of the reservoir (Topic 8-12). In addition, the source of suspended particles containing ^{137}Cs was clarified from sea current and wave data (Topic 8-13).

Determining how radioactive Cs released into the environment is retained for long periods of time in ecosystems is important for clarifying environmental dynamics. Therefore, the microscopic distribution and chemical form of ^{137}Cs in lichens, which are known to retain radioactive Cs for long periods of time, were investigated using a combination of various analytical techniques, to clarify the mechanism of long-term retention (Topic 8-14).

In the FDNPS accident, Pu from nuclear fuel might have been released into the environment. To distinguish this Pu from the Pu originating from global fallout, etc., it is necessary to determine the isotopic composition. As the conventional method of measuring radioactivity in Pu requires a long time to separate interfering nuclides, a rapid analysis method using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was developed (Topic 8-15).

In the development of monitoring and mapping techniques, it is important to assess exposure doses based on air radiation dose rates, the distribution of radioactive materials and the daily behavior of the population to lift evacuation orders. A comprehensive review of exposure dose assessments by various organizations was conducted, and the methods, characteristics, and points were systematically organized for future use (Topic 8-16).

We have been generating R&D results that are the key to achieving the milestones of the medium-/long-term roadmap for decommissioning. We are evaluating the data that contribute to the planning of the lifting of evacuation orders by local governments for environmental restoration and providing these data to the relevant organizations. We are also working to improve the understanding of local residents and others involved by disseminating and sharing information on the status of decommissioning and other initiatives through collaborative projects with local communities and educational institutions, events, and press releases. Furthermore, we are contributing to the improvement of technology, regional revitalization, and job creation in Hamadori area of Fukushima through the participation of local companies and the promotion of technology transfers in the implementation of R&D results in the field.